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JOURNAL OF THE AERONAUTICAL SCIENCES

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Measurement of Altitude Under New F.A.I. Rules*

W. G. BROMBACHER, *National Bureau of Standards*

(Received September 16, 1936)

Introduction

THE new regulations of the Fédération Aéronautique Internationale (FAI) governing attempts to break existing aircraft records, which are above 10,000 meters (32808 feet), went into effect on July 1, 1935.[1] These regulations were prepared on the basis of the experience of a European meteorological service in making airplane flights to obtain meteorological data. In the opinion of the writer modifications are essential in the method of installation of the instruments, in the specification of the instruments to be used, and in the testing technique. It is the purpose in the present paper to give a digest of the new regulations and to set forth for discussion the modifications which seem desirable.

The FAI anticipated changes in the regulations since a provision was adopted which permits any procedure and instruments to be used by means of which an accurate record of air temperature and air pressure throughout the flight is obtained. It is specifically provided that before acceptance of the record, the corrections applied to the readings of the official meteorograph must have the approval of a competent committee of the FAI. It is not clearly stated in the regulations whether or not approval of the use of a method of measurement different from that specified must be obtained before the flight, but it is quite clear that any material deviation from the regulations must finally pass a FAI committee in order to be accepted.

Digest of the New Regulations

In the new regulations the method of calculating the altitude has been changed radically from that followed since 1920. Formerly the lowest pressure in flight was measured and converted to an altitude by the altitude-pressure-relation of the FAI standard atmosphere. It is now required that the maximum altitude of the aircraft above sea level be determined by means of the common barometric formula in which altitude is expressed as a function of air temperature and air pressure.

The barometric formula in a form equivalent to that specified in the regulations is as follows:

$$H = 18{,}400 \frac{T_m}{273} (1 + 0.00259 \cos 2\Psi) \log \frac{P_o}{P} + h_o + A + h'$$

where

H = altitude above sea level in meters
T_m = mean temperature of air column in absolute degrees centigrade.
ψ = latitude of point of take-off.
P_o = air pressure at ground level.
P = air pressure at highest altitude.
h_o = elevation of point of take-off above sea level, in meters.
h' = vertical distance of the meteorograph either from the center of the balloon or from the fore and aft axis of the airplane, in meters.
A = An additive constant to compensate for the variation of gravity with altitude and for the assumption of a mean relative humidity of the air of 60%. At 10 km., A = 25 m.; at 15 km., 44 m.; at 20 km., 72m.; at 25 km., 107 m.

A new record is recognized only when the current record is broken by 200 meters (656 feet) at altitudes between 10,000 and 11,000 meters; and 300 meters

* Discussed at the A.S.M.E. National Technical Aeronautic Meeting held at St. Louis, Mo. on October 10 to 12, 1935. Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

[1] Bull. *FAI*, p. 61, No. 60, Jan., 1935.

(984 feet) at altitudes above 11,000 meters (36089 feet). It is to be noted that at 50,000 feet the change in air pressure for 300 meters change is 4.1 mm. of mercury; at 75,000 feet, 1.2 mm. of mercury.

In flight the following observations must be obtained by means of recording instruments:

(a) The air pressure from the ground level to the highest altitude of the aircraft and similarly:

(b) The air temperature.

The air pressure at the ground level and at the highest altitude, and the air temperature corresponding to the air pressure at all altitudes during the ascent (from which T_m is computed) must be accurately obtained from the record. The following data are to be obtained by observers on the ground:

(a) The elevation above sea level of the point of take-off.

(b) The latitude of the point of take-off.

(c) The vertical distance of the recording instruments from the center of the balloon, or from the fore-and-aft axis of the fuselage of the airplane, whichever applies.

The type of instrument specified to obtain the flight observations is a meteorograph designed to record air pressure and air temperature upon the same chart. The regulations provide that one, or if possible, two such instruments be installed on the aircraft, one marked "official" and the other "alternate", the record obtained with the latter not to be used unless the official instrument fails to function. The directing official must lead seal these instruments in addition to complying with other formalities which need not be discussed here. The instrument shall be so designed that the record is made by a stylus tracing on a smoked metal foil, such as of aluminum. Neither the sensitivity nor the accuracy of the meteorograph is specified except as it may be implied in the regulation that the air pressures are to be given to the nearest 0.1 mm. of mercury in the report on the altitude determination.

The new regulations contain a detailed description of the procedure to be followed in testing the meteorograph before the flight. Test of the instrument subsequent to the flight is frowned upon. The necessary temperature and pressure data are to be obtained from the flight record by using the calibrations obtained before the flight. Of these provisions it is important to note that "the final calibration test of the meteorgraph shall be made not more than 15 days before the attempt to break the altitude record" and further that "the meteorograph must be 'seasoned', that is subjected to a pressure cycle from normal pressure to 50 mm. of mercury and return, once every 24 to 36 hours in the interval of time between the calibration tests in the laboratory and the flight."

The manner of installation of the meteorographs varies for different types of aircraft as outlined below.

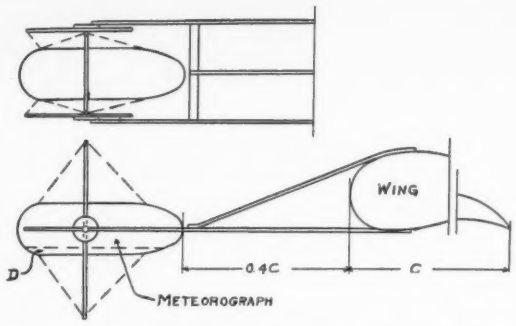


FIG. 1. FAI method of installing meteorograph in airplanes. The meteorograph must be free to swivel in pitch and must be statically balanced. The temperature element is installed in duct D.

Free balloons. The meteorographs installed in a basket with a sunshade shall be suspended 10 meters below the gondola. The basket shall be lowered before the balloon has attained an altitude of 100 meters, and raised just before landing.

Airplanes, seaplanes, amphibians, and gliders. The meteorograph shall be installed at a point along the wing chord 40% of the wing chord in front of the leading edge of the wing, at least one meter from the propeller tip and at least ⅛ of the wing span in from the wing tip. In the case of gliders the meteorograph shall be installed as stated above except that laterally it shall be installed at a point ¼ of the wing span in from of the wing tip. Fig. 1 shows the essential features of the installation.

The meteorograph shall be mounted in a streamlined case and shall be free to head into the wind about an axis parallel to the lateral axis of the airplane. The air speed in the ventilating duct of the temperature element shall not exceed 25 meters per second (56 m.p.h.). The meteorograph shall be shock mounted, preferably by shock absorber cord. Vibrations which give a wide trace on the chart are to be eliminated by adjustment of the shock absorbing mounting. If a wide trace is obtained in the flight, the indications of the edge giving the lower altitude shall be used.

Autogyros and helicopters. In flight the meteorographs shall be suspended 15 meters below the aircraft. Experiments shall be made to insure that the pressure elements are subject to static pressure within 0.5 mm. of mercury.

PROPOSED MODIFICATION OF THE REGULATIONS

These are the essential features of the new regulations. Compliance with every detail is impractical or unnecessarily difficult. Furthermore, the accuracy of measurement can be improved. It seems to the author that certain modifications are very desirable.

Airplanes and Seaplanes.

The chief objection to the new regulations is that the installation of the meteorograph requires the addition of a structure to the wings of the airplane. See Fig. 1. It is of the utmost importance to avoid this additional structure since it will inevitably reduce the maximum altitude attainable. It is believed that a simpler method of installation is absolutely essential.

It may be said at this point that no meteorographs, because of lack of sensitivity of the pressure element, are now available which will give accurate data either when installed as specified or when more satisfactorily installed. A satisfactory installation of instruments of sufficient accuracy can be secured with some development work. The possibilities are discussed below.

(1) *Meteorograph.* The instrument proposed for use is a meteorograph similar to that specified in the new FAI regulations which records air pressure and air temperature. The instrument shall however have adequate sensitivity and be designed to measure air pressure and temperature accurately when installed on the airplane at any convenient point in the free air outside of the slip stream of the propeller. The instrument shall have an air duct in which the temperature element is mounted, similar to that required by the FAI regulations. During flight the air speed through the duct shall be between 15 and 25 meters per second (34 to 56 m.p.h.).

To measure the true static pressure of the air, the pressure element of the meteorograph shall be subjected to this pressure as obtained from a properly installed static tube. In most cases the static tube of the pitot-static tube of the airspeed meter can be used. When the location of the pitot-static tube is inconvenient or when the true static pressure is not produced with sufficient accuracy, a separate static tube should be installed. A relatively simple modification of the conventional type meteorograph serves to subject the pressure element to the static pressure from a static tube. It is relatively impractical to make the case of a meteorograph airtight. Instead, the pressure capsules and as much of the mechanism as is necessary are enclosed in an airtight box except for a nipple for connection to the static tube. A long bearing is used to bring the shaft or the connection through the box so that the mechanism or pen arm can be attached. Without much increase in friction such a bearing can be made air tight against a differential pressure of 3 to 4 inches of water, a value greater than ordinarily needed in service. The use of the long bearing in this way is not experimental. This arrangement has been used on an airspeed recorder constructed at the National Bureau of Standards by F. Cordero and also by Badin (Paris).

The air pressure shall be recorded on as open a scale as possible. Flight test barographs such as the Friez double traverse type have an effective stylus travel of 10 inches for the range, which in an instrument designed for high altitude flights is approximately 800 mm. of mercury. At this sensitivity a stylus motion of 0.01 inch which is at the practical limit of easy detection, corresponds to a pressure change of 0.8 mm. of mercury. Pressure should not be measured with much less sensitivity than this.

Considering now the sensitivity of the temperature element, a stylus motion between 3 and 4 inches is ample for the range of temperature encountered, from +40° to —70°C. This gives a minimum stylus deflection of 0.03 inch per degree Centigrade change in temperature.

On the basis of the above analysis meteorographs now available measure pressure with insufficient sensitivity. There is need for a meteorograph designed especially for high altitude flights. The development of such an instrument should not be difficult as the type of instrument now used in obtaining meteorological data in airplane flights can be suitably modified or a thermograph can be added to the double-traverse type of flight test barograph.

(2) *Photographic recording.* An alternative and perhaps preferable method for airplanes and seaplanes is to photograph simultaneously the indications of an aneroid barometer and of an electrical resistance thermometer. A sensitive altimeter would be practically as satisfactory as an aneroid barometer. If the aneroid barometer is not equipped with an indicator of instrument temperature, a detached thermometer should be photographed. A watch should be photographed and perhaps also a card showing the date, the signature of the directing official and pilots, etc. The arrangement can be such that photographs can be taken at any convenient interval of time, depending upon the rate-of-climb, as for example every 15 seconds would be satisfactory for fast-climbing airplanes.

In order to secure a continuous record of air pressure it is also advisable to require the installation of a double traverse barograph of the type commonly used in this country in high altitude flights under the old regulations. This instrument must however be equipped with a recorder of instrument temperature, and should be designed so that the pressure element can be subjected to static pressure from a suitable static tube, as discussed in the previous section for the pressure element of the meteorograph.

The use of these indicating instruments would greatly simplify the problem of installation. A box containing the instruments, the camera and necessary controls would be installed in the fuselage. Three external connections would be necessary. First, it would be necessary to connect the case of the aneroid barometer to a static tube. Second, the temperature element, consisting of a resistance element contained in a tube about one inch in diameter, and weighing

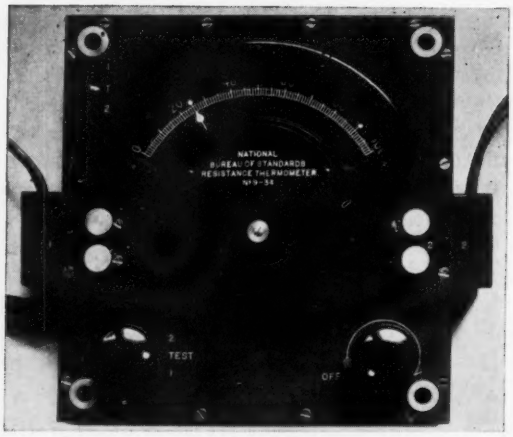


FIG. 2. Indicator unit of electrical resistance thermometer for measuring air temperature.

complete not more than one-half pound, would be installed at any convenient point on the airplane in the free air, not in the slip stream, and connected to the indicator unit by means of the usual electrical leads. A further connection for a battery (12 volts) would complete the external connections to the instrument box.

While some development work is needed, there is no doubt of the feasibility of photographic recording. Resistance thermometers of the type suitable for the purpose have been in use by the Navy flight test section for many years.[2]

The indicator unit is similar to that shown in Fig. 2. The Navy temperature element is shown in Fig. 3.

An aneroid barometer has been developed by Kollsman for use in the National Geographic Society-Army Air Corps stratosphere balloon flights which is also admirably suited for the measurement of air pressure in airplane flights. The instrument has two pointers, one of which makes one revolution for each 100 mm. of mercury pressure and the other one revolution for the pressure range, 0 to 800 mm. of mercury. The case is airtight except for a nipple which is for connection to a static tube. A photograph of the aneroid barometer is shown in Fig. 4. It is seen in the figure that an indicator of instrument temperature is provided, which is essential to apply the corrections for the effect of instrument temperature as required in the regulations. One of the aneroid barometers was compensated for temperature at all pressures, in which case the indication of instrument temperature is unnecessary.

A photographic unit of a suitable type, including the exposure interval control, has been developed by A. W. Stevens for use in stratosphere balloon flights.

[2] J. B. Peterson and E. W. Rounds, *SAE Trans.*, p. 231, Vol. 25, 1930.

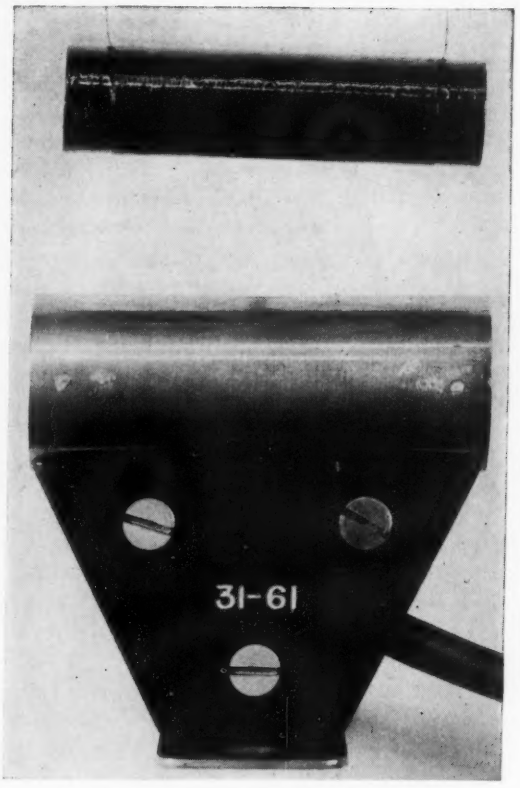


FIG. 3. Resistance element of electrical resistance thermometer for airplanes. This is mounted so as to be exposed to the free air.

Free Balloons.

The chief objection to the regulations for installations on free balloons is the lack of consideration of the inherent difficulty of measuring the air temperature accurately. It is absolutely essential that the temperature element be ventilated during flight. Without such ventilation the air temperature will not be recorded accurately owing to the heat capacity of the element itself and, more important, that of its supports.

Another source of error difficult to avoid is the effect of the balloon. While the balloon is rising the instrument passes through the air behind the balloon. The latter is not at the air temperature and therefore affects the air temperature near itself. Available data indicate that this error is not likely to be serious except while leveling off or during the initial stages of the climb after a period of level flight.

It is proposed in balloon flights to photograph on the same film the indications of an electrical resistance thermometer, an aneroid barometer, aneroid barometer temperature, a watch and certain identifying data such as the date, directing official's signature, etc.

FIG. 4. Kollsman aneroid barometer. The instrument temperature is indicated on upper inset dial. The pointers of both the lower inset dial and the main dial are read to secure a pressure reading which is 752 mm of mercury.

In order to have a continuous record of the air pressure it is desirable to require that a sealed barograph also be carried in flight.

The temperature-sensitive resistance element of the thermometer should be installed in a duct about 12.5 cm. (5 inches) in diameter and should be mounted in the free air at some distance below the gondola, say 10 to 20 meters. It should be ventilated by an electrically driven fan, the fan exhausting from the duct. The indicator unit should be installed in the gondola. The indications of the thermometer together with those of an aneroid barometer should be photographed by a movie camera, at intervals of one to two minutes. These readings would serve to determine the mean temperature of the air column and also the required air pressures.

Both the aneroid barometer and barograph should be continuously vibrated during flight in order to avoid the effect of friction on the indication and both must be provided with a means for measuring instrument temperature. In airplanes, sufficient vibration is present from the motor but in balloons the vibration must be provided by a special device.

A resistance thermometer suitable for use in free balloons was developed for the National Geographic Society-U. S. Army Air Corps stratosphere of 1934[3].

FIG. 5. Resistance element of electrical resistance thermometer for balloons. Ventilation is provided by the electrically driven fan at the rear of the unit.

The temperature element of this instrument is shown in Fig. 5. Ventilation was secured by means of a fan driven by a permanent field electric motor requiring a maximum of but 20 watts for operation. This unit was developed by Stevens. The motor operated satisfactorily in an air bath at a temperature of —70°C. The indicator unit, shown in Fig. 2, was provided with connections for two resistance elements, either one of which could be used to obtain an indication as desired.

The aneroid barometer described previously, Fig. 4, was developed for use in stratosphere balloon flights and is satisfactory for use in record flights.

A double traverse barograph of the type used in record altitude flights under the old regulations should also be provided to secure a complete record of the air pressure. This instrument should be provided with an instrument vibrator. A small 3-volt buzzer mounted on the base of the barograph is satisfactory. In a balloon flight the use of a static connection to secure static pressure is unnecessary since the balloon velocity relative to the air is small.

Meteorograph. An alternative installation for free balloons is the use of a meteorograph as provided in the present regulations but with some modifications. The requirements relative to the use of a meteorograph would be improved by requiring artificial ventilation for the temperature element. This is no assurance that temperature will be measured accurately because the circulation may be inadequate to eliminate lag. The difficulty in eliminating lag is increased because it is believed preferable to insulate thermally the rest of the instrument in order to secure operation at low temperatures of the clock which drives the recording drum. Judgment on the

[3] A. W. Stevens, *Nat. Geog. Magazine*, V. 66, p. 397, October 1934. W. G. Brombacher, *Nat. Geog. Soc. Technical Papers, Stratosphere Series*, p. 15, 1935.

sufficiency of artificial ventilation must await further experience.

A recorder of instrument temperature, more accurately of the pressure element temperature, is an essential addition to the meteorograph so that correction can be made for the effect of temperature changes on the indications of pressure. It should be noted that no connection to a static tube is necessary.

Autogyros and Helicopters.

No modifications for these classes of aircraft are considered at present in view of the improbability at the moment of flights to altitudes above 10,000 meters.

Instrument Tests

In addition to changes in the selection of instruments and their installation, modifications in the testing technique are also desirable. The provision that the final laboratory test must not precede the flight by more than 15 days should be modified. If a poor quality instrument is used. which is not prohibited by the regulations except by inference, the accuracy of the altitude determination is below par no matter how and when tests are made. The length of time a good quality instrument holds its calibration depends more on the handling it receives than on the length of time after tests, up to at least six months. It is obvious that requiring tests within 15 days of the flight is a serious inconvenience in this country while on the other hand it would impose no hardship in most countries in Europe.

The requirement that the meteorograph be seasoned daily is considered unnecessary if the laboratory tests are required to be made on "rested" instruments. If an instrument has excessive changes in calibration in tests made at 24 hour intervals, it should not be used since daily seasoning will in no case insure accuracy. In the procedure to be outlined below seasoning is eliminated.

In omitting the requirement that laboratory tests of the instruments after the flight be made, the statement is made that such tests are of little value owing to violent shocks experienced in landing. To depend entirely upon a calibration of an instrument made before the flight appears warranted only because of its simplicity. A change in calibration can occur as readily from a shock to the instrument during its transportation to the place of the attempted record flight. It must be determined whether or not a change has taken place in its calibration. A test at one pressure or temperature after the flight is a simple and adequate procedure, since shifts in good quality instruments are usually that of the entire calibration curve parallel to itself. If a change is shown thereby to have taken place, other data must be available so that the official testing laboratory can arrive. if possible, at an accurate value of the altitude, without voiding the altitude attempt. To throw away these easily taken safeguards of accuracy is indefensible in view of the high cost of such flights.

The following procedure is suggested as practical and serves to obtain accurate results:

(a) Test the instruments in the laboratory not more than two, or perhaps three, months before the flight. These tests shall include calibration of the barograph, pressure element of the meteorograph, or aneroid barometer, depending upon which is used, at three temperatures: at approximately $+30°C$, at as low an instrument temperature as may be expected in flight and at an intermediate temperature. The thermograph or thermometer shall be calibrated in the temperature range which is expected during the flight. Auxiliary tests to determine the elastic quality of the instrument elements and the frictional effects shall be made.

(b) The directing official shall obtain the value of the air pressure and air temperature at the time and place of take-off. If possible the quantities shall be measured also at the time and place of landing. The air pressure should be measured by a mercurial barometer if possible which in most cases can be done by arranging for such measurements with local Weather Bureau stations.

Comparison of the values before and after the flight of the ground level values of air temperature and pressure with the corresponding indications of the official flight instruments will indicate whether or not their calibrations have changed at each control point.

(c) In the official laboratory, after the flight the instruments shall be read at the ambient air pressure and temperature simultaneously with a mercurial barometer and a calibrated thermometer. The difference in the instrument readings from the true values of pressure and temperature will show whether or not any change in calibration has taken place and also serve in some measure to check the data obtained by the directing official in the field.

(d) If no changes in calibration are indicated subsequent to the take-off it is advisable to give the pressure element a "flight history" test solely to determine the lowest pressure attained in the flight. This eliminates the effect of the drift or "creep" upon the reading of the pressure element since the time of ascent to the lowest pressure is rarely the same as that taken during the original calibration tests. If the lowest pressure thus obtained checks the value obtained by the original calibration within one millimeter of mercury it can be stated that the work throughout is upon as scientific a basis as is now possible.

(e) Correction for shifts in the calibration curves which are definitely established to have occurred before take-off or after landing can usually be made if the data specified in (b) are available to the official testing laboratory. Such correction should be made whenever it can be done accurately. Correction for shifts during flight are difficult to make accurately and must be handled as the available evidence indicates. Taking account of the shift in such a manner as to give the lower altitude appears to be a safe procedure.

Summary

The new FAI regulations governing attempts for international records for altitudes above 10,000 meters, a digest of which is given in the paper, are far from perfect either as regards choice of instruments, manner of installation or the testing technique. Summarizing the discussion in the body of the paper it is considered that the following choice of instruments is preferable.

For airplanes and seaplanes: either

(a) Meteorograph of adequate sensitivity measuring free air pressure and air temperature, having a pressure element connected to a properly located static tube, and temperature element mounted in a duct. Should be equipped with a recorder of the pressure-element temperature.

The meteorograph should be installed on the aircraft at a point at least one meter from the propeller tip and so that free air flows through the thermometer duct during flight.

(b) Photographic recording of the indications of a resistance thermometer, of an aneroid barometer and of a watch. The aneroid arometer should be equipped with an indicator of instrument temperature, and should be connected to a properly located static head. The temperature element of the thermometer should be installed on the airplane exposed to the free air, at least one meter from the propeller tip; the other apparatus, in the fuselage.

A barograph is required to secure a complete record of pressure. It should be installed in the fuselage and be equipped with an instrument temperature recorder and be connected to a properly located static tube.

For balloons: it is preferable to have

(a) Photographic recording similar to that described above for airplanes. The aneroid barometer should be provided with an electrically operated vibrator and does not require connection to a static tube. The temperature element of the thermometer should be installed below the gondola so as to be exposed to the free air and be ventilated in flight by an electrically driven fan.

(b) A meteorograph, to be hung 10 meters below gondola, is not recommended owing to the difficulty of measuring air temperature. The temperature element should be in a duct through which air can circulate. Artificial circulation should be provided through the duct. No static tube is required for the pressure element. An electrical vibrator and a recorder of pressure-element temperature are required.

The important changes advocated in the testing technique are (a) the elimination of daily seasoning of the barograph or pressure element of the meteorograph up to the day of the flight; (b) the permitting of tests to be made as much as two or three months before a flight; instead of fifteen days; (c) the additional provision that the directing official obtain data on air pressures and temperatures at the ground level at the time of take-off and if possible at landing; and (d) that laboratory tests of the instruments shall be permitted subsequent to the flight. In general, tests of the instruments and the data obtained by all concerned should be to the end that values of pressure and temperature shall be obtained as accurately as possible.

A Method of Figuring Shear and Torsion in Multispar Wings

FELIX NAGEL, *Douglas Aircraft Company*

(Received July 31, 1936)

ONE of the problems the airplane designer is confronted with is to figure the torsion in wings covered with metal, plywood or using a "double drag bracing." The method most frequently used is to determine the so called "elastic axis," and figure the torque in multiplying the resultant load on a wing panel by the distance from this axis. The shear in the covering is then figured by the well known Saint Venant formula.

Thus the problem is reduced to the task of finding the "elastic axis," which, unless derived from tests, is usually assumed to coincide with the "center of gravity" of the moment of inertias of the individual spars. It will be noted that, in "monocoque construction," a spar can be substituted by a shear web with skin stiffeners and adjacent "effective width" of skin.

Now, every "spar" in the wing carries a certain shear load. If the distribution of shear loads between spars would be known, a line of resultant shear at each "station" could be figured, which would be at the "center of gravity" of the shears of the individual spars. This "line of resultant shear" may have the distance s from the leading edge of the wing at the respective station located at a distance x from the outside tip of the wing. For the resultant load R on the wing panel, (in most cases the difference of air load and "dead weight" of the wing) let r be this distance from the leading edge, (see Fig. 1). The torque moment at each station then becomes

$$Q = \text{resultant load } (s - r) = R\,(s - r) \qquad (1)$$

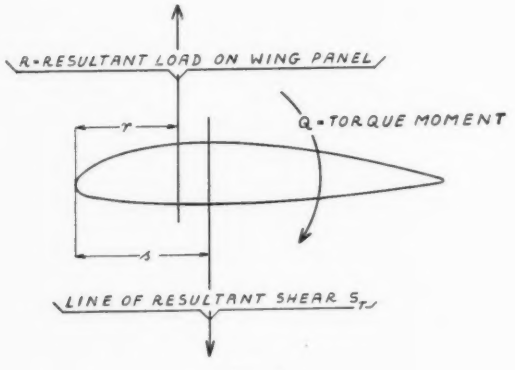


FIG. 1.

From this it follows that it is not necessary to find the "elastic axis" at all if the distribution of shear between spars is known, which is required in any event to design its shear carrying members properly. It might even be said that the "elastic axis" does not necessarily give the correct answer at all, even if its exact location should be known. The problem is therefore to find the distribution of shear between the spars. For its solution, a simple method based only on fundamental and well known equations is offered. The following symbols are used.

Symbol	Abbreviation for	Dimension
c	chord length at respective station..	length
d	differential.....	0
I	moment of inertia of individual "spar"	length ^{4}
I_T	moment of inertia of total wing...	length ^{4}
Q	torque moment in wing (taken by covering)	force x length
r	distant of resultant load R from leading edge at respective station.	length
R	resultant load on wing panel outside of respective station.	force
s	distance of line of resultant shear from leading edge at respective station.	length
S	shear load in individual spar.....	force
S_T	total shear load in wing panel outside of respective station (=R).	force
T	subscript for total wing panel.....	0
x	distance of station from outside tip of the wing.	length
x_r	distance of resultant load R from respective station, measured parallel to span.	length
y	distance of shear carrying member of "spar" from leading edge.	length
Σ	summation.....	0

Let M represent the bending moment of an individual spar, and x a distance parallel to the spar. Then the shear becomes $S = dM/dx$.

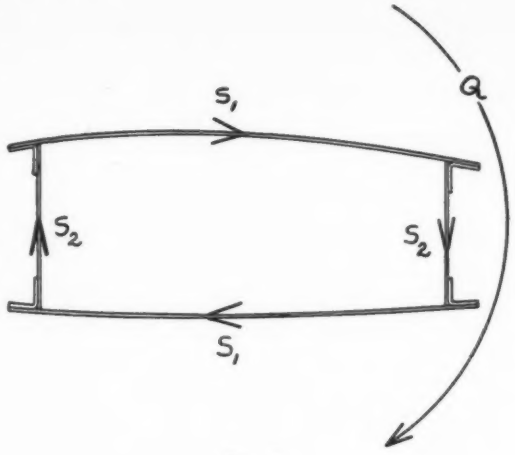


FIG. 2.

If the bending moment in each spar would be known, the shear could therefore be easily obtained. For wings with an outside skin this moment is not affected by the torsion Q to any considerable amount, this result being well established by tests. A more qualitative explanation based on the least work theorem is as follows:

Consider, for instance, a box built up of two spars and the outside skin, as shown in Fig. 2.

The torque Q can be resisted by bending of the spars only with considerable stresses in the spar flanges, or it can be resisted by relatively low shear stresses resulting from the loads S_1 and S_2 and no loads in the spar flanges at all. The work done by the system is in each case given by

$$\text{Work} = (C/E)\ \Sigma\ \text{volume} \times \text{stress}^2$$

where C is a dimensionless constant, E the modulus of elasticity, and Σ the summation symbol. If this summation is carried out in practical cases, it will be found that it is of the order of 100 times larger if the torsion is taken by the spars alone compared with that taken by shear stresses only. It can easily be shown that this factor of the order of 100 becomes less only at the station where the torque Q is taken out, in most cases at the fuselage connection. Therefore, in order that the work done by the system become as small as possible, the torsion will be taken by shear alone rather than by bending in the spars.

From this it follows that the bending moment M in each spar is directly proportional to $E \times I$, where I is the moment of inertia of the individual spar:

$$M = M_T \frac{I E}{I_T E_T};\ M_T = \Sigma M;\ I_T E_T = \Sigma I E$$

In almost all cases the spars are built of the same material:

$$M = M_T \frac{I}{I_T}$$

Differentiating with respect to x,

$$\frac{dM}{dx} = \frac{1}{I_T}\left(M_T \frac{dI}{dx} + I \frac{dM_T}{dx} - M_T \frac{I}{I_T}\frac{dI_T}{dx}\right)$$

or

$$\frac{dM}{dx}\frac{I_T}{M_T} = \frac{dI}{dx} + I\left(\frac{1}{M_T}\frac{dM_T}{dx} - \frac{1}{I_T}\frac{dI_T}{dx}\right)$$

Now

$$\frac{1}{M_T}\frac{dM_T}{dx} = \frac{S_T}{M_T} = \frac{1}{x_R}$$

where x_R is the distance of the resultant load on the wing panel outside of the station to be considered from this station, measured parallel to the span.

Substituting:

$$\frac{dM}{dx} \times \frac{I_T}{M_T} = \frac{I}{x_R} + \frac{dI}{dx} - \frac{I}{I_T}\frac{dI_T}{dx} = S\frac{I_T}{M_T} = [\text{Length}^3]$$

The percentage of shear taken by each individual spar is

$$\frac{S}{S_T} = \frac{S \times x_R}{M_T},$$

and from the previous equation

$$\frac{S}{S_T} = \frac{I}{I_T} + \frac{x_R}{I_T}\left(\frac{dI}{dx} - \frac{I}{I_T}\frac{dI_T}{dx}\right) \qquad (2)$$

Let

c = chord length of the wing

s = distance of line of resultant shear from leading edge

y = distance of a shear carrying member from the leading edge, all measured at the station to be considered.

Then

$$s = \sum \frac{S \times y}{S_T};\ \frac{s}{c} = \sum \frac{S}{S_T} \times \frac{y}{c}$$

Substituting from Eq. (2)

$$\frac{s}{c} = \sum\left[\frac{I}{I_T} + \frac{x_R}{I_T}\left(\frac{dI}{dx} - \frac{I}{I_T}\frac{dI_T}{dx}\right)\right]\frac{y}{c} \qquad (3)$$

From this last equation the conclusion can be drawn that the line of resultant shear coincides at the wing tip ($x_R = 0$) with the "center of gravity" of the moment of inertias of the individual "spars." This also will not be altered, if going inboard from the tip all spars increase their moment of inertia at the same percentage, the term

$$\frac{dI}{dx} - \frac{I}{I_T}\frac{dI_T}{dx}$$

in Eq. (3) then becoming zero. However, it will leave the "center of gravity" location and shift to those spars whose percentage increase in moment of inertia is higher, if this is not the same for all spars.

Friction Losses in an Artificially Roughened Rectangular Channel

WILSON TRIPP, *Kansas State College*

(Received October 6, 1936)

Summary

FROM a series of tests at the University of California[1] on groove roughness, data was obtained to correlate the friction factors and the relative roughness of the channel walls. The results have been compared to Nikuradse's analysis of granular roughness. The experiments were made with air.

Features of Apparatus

A rectangular channel was constructed of 2-inch redwood boards and so arranged that its width could be varied by changing the top and bottom spacers. One-eighth inch by one-eighth inch square grooves spaced 5/8" on centers were cut into the boards transversely to the stream flow. The same grooves and side walls were used throughout the experiment. Thus the absolute roughness remained constant, and the relative roughness was varied with the channel widths. The widths used (as measured from lands to lands) were 1.08 in., 2.08 in., 4.16 in. and 6.01 in. A constant channel height of 22½ in. was maintained.

Air entered the channel through a bell-mouthed inlet which had been calibrated as a quantity-rate meter using a Pitot tube traverse as the standard of comparison. The velocity across the inlet section was very nearly uniform.

Pressure and velocity distribution measurements were made by means of six pressure and two velocity sections situated along the channel. These measurements were made to within 1/100 of an inch of water.

Experimental Results and Analysis

The results of the velocity distribution measurements showed that the velocities were symmetrically distributed about the center line of the channel. Fig. 1 shows the results of the friction measurements. The length parameter in the Reynold's number equals four times the value of the hydraulic radius.

The line in Fig. 2 shows the results obtained by Nikuradse for rough surfaces when sand grains glued to the sides of a circular pipe formed the roughness. This line corresponds to the formula

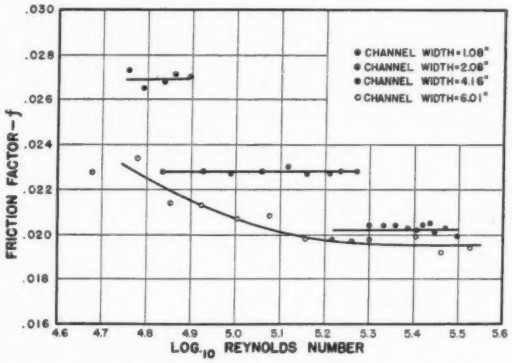


FIG. 1. Friction factor as a function of Reynold's Number.

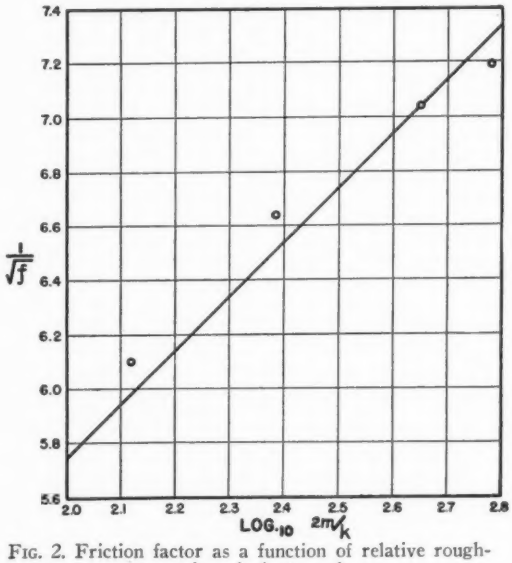


FIG. 2. Friction factor as a function of relative roughness of equivalent sand.

$$\frac{1}{\sqrt{f}} = 2.0 \log_{10} \frac{r}{k} + 1.74 \qquad (1)$$

where

f = friction factor from pipe friction equation.

$h = f \frac{l}{d} \frac{v^2}{2g}$

r = radius of pipe.

k = diameter of sand grains used as roughness.

Twice the hydraulic radius of the rectangular channel was substituted for the radius of the circular pipe. Eq. (1) then becomes

[1] The work reported here is part of an extensive program on the friction losses in channels artificially roughened with triangular and rectangular grooves using both air and water as fluid media. The author obtained the data for this article while a graduate student at the University of California.

$$\frac{1}{\sqrt{f}} = 1.74 + 2.0 \log_{10}\left(\frac{2m}{k}\right) \qquad (2)$$

where

m = hydraulic radius.

The plotted points of Fig. 2 were obtained as follows: the values of f and 2m for the 4.16 in. wide channel were substituted in Eq. (2), giving k = 0.000652 ft., which may be thought of as the equivalent granular roughness of the grooves in the 4.16 in. wide channel. This value of k was then used in calculating the values of $\log_{10}$ (2m/k) for the three remaining channel widths. The experimental values of the friction factor f plotted versus log (2m/k) are within 2½ per cent of the friction factors as given by Eq. (2).

Conclusions

Within the accuracy of the experiment, it has been shown experimentally that the friction factors for a certain type of rough surface can be computed from Nikuradse's equation for any relative roughness provided that the equivalent granular roughness of that surface is known.

Plastics Appear on Aircraft

JACK DELMONTE, *E. Lansdowne, Pennsylvania*

(Received October 3, 1936)

MODERN plastics are gaining popularity in industry because of the wide range of applications to which these materials lend themselves. In aircraft they are of immediate concern, because of advantages not found in other materials. While the application of plastics to aircraft structures is still in its infancy, and hence requires considerable discussion to qualify the contention, plastics have demonstrated superior characteristics in miscellaneous accessories used upon aircraft. The requirements for aircraft accessories include: non-inflammability, flexibility, weather reistance, ease of machining, erosion resistance and good di-electric qualities. To these requirements may be added additional structural demands; high strength-weight ratio, freedom from shrinkage, smooth exterior surface, ease of attachment or joining of parts, and low cost as compared with the present structural materials.

No one plastic satisfies all of these requirements to the optimum advantage, but all may be met by careful selection of plastic materials from the large number which have appeared upon the market within the last few years. Whereas, prior to the expiration of the bakelite patents several years ago, bakelite and plastics were synonymous, the product bakelite is now one of many. The total plastic output in 1935 was 100,000,000 pounds with a valuation of $50,000,000. In 1930 it was but 31,000,000 pounds.

Plastics are basically of organic origin, that is to say, they are combinations of carbon with hydrogen, oxygen, nitrogen, and other elements. A suitable classification of the plastic materials may be established by listing the products in accordance with their origin. This classification is important to those interested in plastics, as it arranges the large number of products into a more intelligible order. Particular attention is invited to groups I and II of Table 1, as these materials are used most frequently upon aircraft.

In lieu of Table 1, plastic materials are classified sometimes by their behavior toward temperature. There are two groups comprising this classification: (1) Thermoplastic and (2) Thermosetting. A thermoplastic substance is rigid under normal temperatures and stress, but it deforms under heat and pressure. In this classification come the groups I, IIc, and III of Table 1. The thermosetting substances are initially thermoplastic, but in the process of applied heat and pressure they become permanently infusible, undergoing complete chemical and physical changes. In this classification come the groups IIa, IIb, IV, and V of Table 1. The latter group is favored for molding processes as the finished product can be removed from the mold, without the supplementary cooling required for thermoplastic substances to prevent deformation.

TABLE 1

Classification of Plastics

	Origin	*Typical Forms*	*Typical Trade Names (United States)*
I	Cellulose Derivatives		
	a. Cellulose Nitrate.	Sheet, tubes, rods.	Pyroxylin, Celluloid, Viscoloid, Pearloid, Nixonoid, Fiberloid.
	b. Cellulose Acetate.	Sheet, tubes, rods.	Acelloid, Celanese, Fibestos, Kodapak, Lumarith, Masuron, Plastacele, Tenite.
	c. Ethyl & Benzl,	Solvents.....	Tylose, Glutoline.
II A	Synthetic Resins Phenol-Formaldehyde Group		
	a. Molded.....	Miscellaneous Forms.	Bakelite, Durez, Durite, Makalot, Resinox, Richware, Pyroplax, Textolite.
	b. Laminated.....	Sheets, rods, tubes, bars, fabricated parts.	Aqualite, Formica, Synthane, Micarta, Textolite, Campbellite, Celeron, Insurok, Panelyte. Phenolite, Dilecto.
	c. Cast.....	Sheets, Rods, Slabs, tubes, bars.	Catalin, Marblette, Joanite Catalagulli, Bakelite, Panplastic, Ivaleur, Jewelin, Fiberlon.
II B	Synthetic Resins Urea-Formaldehyde Group		
	a. Molded.....	Miscellaneous Forms.	Beetle, Cibanoid, Harvite, Crystalite, Luxite, Plaskon, Unyte.
	b. Laminated.....	Sheets, rods, tubes, bars, fabricated parts.	Cibanoid, Dilecto UF, Formica, Moldarta, Phenolite.
	c. Cast.....	Sheets, Rods, Bars.	Crystus.
II C	Synthetic Resins Miscellaneous		
	a. Acrylic Resins (methyl or ethyl methacrylate).	Sheet Form, Rods.	Plexiglas, Paraplex.
	b. Rinyl Resins.....	Molded and Sheet.	Vinylite.
	c. Glycerol & Phthalic Anhydride.	Molded and Sheet.	Glyptal.
	d. Styrol.....	Molded.....	Victron.
III	Natural Resins Petroleum Derivatives Rosin Asphalt Pitch Shellac.	Used in various cold molding compositions.	Gumman, Cetec, Thermoplax, Komac, Stoco, Stanolite.
IV	Synthetic Rubbers...	Various.....	Thiokol, Duprene.
V	Proteins		
	a. Soya-bean meal..	Molded.....	Soya Bean (Ford Motor Co.)
	b. Casein.....	Sheets, rods, tubes, molded.	Aladinite, Ameroid, Karolith, Kyloid.

The transparent cellulose derivatives have been applied to aircraft windshields and aircraft safety glass windows for a number of years. Safety glass, it will be recalled, consists of two sheet glass plates between which is sandwiched a thin .020 inch layer of plastic material. Through the use of proper bonding agents the plastic layer is cemented to the glass surfaces. As the absorption of moisture at the edges by the plastic leads to an early deterioration of the safety glass, a bituminous sealing compound is placed around the edges. It was soon found that cellulose acetate was

superior to cellulose nitrate as the plastic layer, as it is more durable against the effects of sunlight and general deterioration. Safety glass appears largely in the transport and passenger airplanes as windows for the cabins.

On smaller airplanes, the windshields and cockpit enclosures are of plastic origin, chiefly cellulose acetate. Cellulose nitrate has passed out of the picture in this respect because of inflammability. The addition of triphenyl-phosphate to the cellulose acetate plasticizer, gives the fireproof characteristic so necessary for aircraft. As safety glass is rigid, curved windshields and cockpit enclosures were made of a solid layer of plastic material, shaped to the desired form. Fig. 1 illustrates a Vultee attack-bomber with a large area of transparent sheet applied over the cockpits. These plastic sheets range in thickness from 1/16 to ¼ inch. The thinner sheets possess greater flexibility.

In the development of safety glass for aircraft and automotive service, two new transparent synthetic resins have appeared, which promise to supersede the present cellulose layer. The acrylic and vinyl plastics are decided improvements over the cellulose types insofar as safety glass is concerned. They possess greater resistance to heat and sunlight. In addition, they require no bonding agent to seal them to the plate glass, and when the glass is shattered, they retain the particles better than the earlier types. Tests upon Vinylite safety glass show shock absorbing characteristics ten times better than the present safety glass at 0° Fahrenheit.

For smaller aircraft, Plexiglas, Glyptal, and Vinylite are available in sheet form. For example, a Plexiglas hood for passenger airplane has been formed of one piece and bent on three sides, permitting an unimpaired view. Glyptal has been used a great deal upon English aircraft and Plexiglas has been used upon German aircraft. These materials are also suitable for aircraft goggles. The fact that they are flexible, permits them to be shaped to any curved surface, which is quite important to aircraft designers in this day of smooth aerodynamical finish.

Dr. Watts, in a paper presented before the Royal Aeronautical Society (Jl. Roy. Aero. Soc. p. 484, July, 1936) outlined a new and very important application of cellulose acetate plastic to propeller design. In pointing out the advantages of wood propellers in safety (freedom from fatigue, absorption of vibration) he mentioned the disadvantages of moisture absorption and erosion. These disadvantages have been overcome by the Schwarz process of protection, whereby the propeller is covered with a layer of cellulose acetate 1 mm. thick. Over the leading edge a thin strip of cellulose is placed, which is covered by fabric or high tensile strength steel gauze covering all of the blade and boss. The leading edge is then covered with a special phosphor bronze wire gauze, to which is sweated a nose piece of brass. The propeller is finally covered

FIG. 1. Vultee Attack Bomber. The transparent plastics over the cockpit enclosure are readily observed.

with a cellulose acetate sheet in a soft and plastic state. On applying a pressure of several atmospheres to the laminated structure, the plastic layer impregnates and adheres to the wood as it forces its way through the fabric and wire gauze into the wood pores. The covering of cellulose acetate may be highly polished to lower the profile drag. In this manner the wood is sealed against the entrance of moisture and a surface is formed which resists erosion, corrosion, and abrasion.

Other plastic materials used in the construction of propellers include micarta, a laminated phenolic formaldehyde. Since 1918, a limited quantity of micarta propellers have appeared for experimental purposes.

MOLDED PLASTICS

The synthetic resins, combined with various fillers, dyes, and lubricants, are furnished in sheets, powder, or compressed pellets. The fillers play an important part in determining the characteristics of the finished product. The molding procedure to follow is determined to some extent by the molding composition and the shape of the finished article. Thus there are, in general, hot molding operations (combinations of heat and pressure), cold molding operations (high pressure), extrusion and injection molding. The latter method is coming into more prominence lately; it is similar to the die-casting of metals. Such processes lend themselves to mass production of molded plastic parts. Preforming by cold molding, prior to hot molding, is sometimes of advantage. The molded product requires very little finishing, and complicated shapes with thin sections, screw threads, letters, designs, and rubber or metal inserts are easily formed.

In many cases a molded plastic part is a good substitute for a complicated metal part requiring machining to the desired form. The economy gained from the use of a plastic part is obvious when making a case for some aircraft instrument. Assuming that shielding is not essential, a molded plastic case for the aircraft instrument is completed in one operation, with a short finishing step to give a high lustre if desired. On the other hand, to prepare this same case from metal requires blanking, forming, trimming, grinding, sand blasting, phosphate finish, japanning, and baking in successive operations. The appearance of the finished

product is decidedly in favor of the plastics, for they are available in a wide assortment of colors, and they have a permanent finish. To give some idea of the cost of the molding compositions, the price of 20 cents a pound was current in 1928 and 12 cents a pound in 1935.

Molded plastic aircraft parts are numerous and are not confined to any particular type of synthetic resin. As will be seen, some plastics possess more desirable electrical qualities and these are particularly applicable to radio equipment. Other molded plastic applications such as the instrument cases already described, are made, for example, of Durez. Dial faces have been constructed of Plaskon. Translucent dials for aircraft instruments have been made from cellulose acetate. In applications of this nature, the choice of material is a matter of individual taste rather than physical requirements. On the other hand, plastic instrument board panels require further considerations of the shock and vibration, which upon aircraft would effect serious damage if improper material was selected. Various instrument knobs, handles, control stick handles, bushings, washers, etc., are of molded plastics. The color of these items can be as desired, though in general they are black; powdered carbon makes a very inexpensive filler for the molding composition, at the same time imparting satisfactory qualities.

In the early Liberty aircraft engines, a phenolic molded distributor head gave good results. Other engine electrical accessories, the starter, magneto, and generator, find frequent use for plastics in their construction for insulating qualities. The fact that the plastics may be machined or molded to any desired form, and that they provide rigid insulating bases, make them indispensable as electrical accessories.

In the airplane slipstream one can find small streamlined plastic acorns separating the wires, plastic covers for the flying lights, and plastic streamlined housings for the rotating loop antennas. If the definition of plastics is strictly followed, the glyceryl phthalate resins may be cited as surface finishing products, but the subject of protective finishes for aircraft is beyond the scope of this paper.

The various fillers which are introduced into molded plastics are discussed in terms of the characteristics of the finished products. From the following data, one should be able to specify the type of molded plastic required for a job, and the filler which would fulfill the requirements most satisfactorily.

Fillers For Molded Plastics

Wood flour filled plastics:—These materials are furnished generally to the custom molder in the form of dry, granular powder. From them are derived the products which exhibit the best electrical characteristics. Bases for radio tubes, switch plates, high dielectric strength insulators, headphones, and microphones are typical aircraft products using wood flour fillers. These fillers impart flexibility to the molded products, permitting articles with heavy metal inserts. Good machining characteristics are possible with these products. This is important when it is not economical to build an expensive mold for only a few products. In that case machining can easily complete the article. The wood flour filler is perhaps the most universally used filler for the thermo-setting plastics.

Asbestos filled plastics:—This group of plastics is distinguished by its ability to resist higher temperatures than wood flour or other organic fillers, withstanding temperatures of 570° F. for short periods of time. Articles with long fibre asbestos have superior mechanical characteristics as compared to the short grain fibers. These plastics are more applicable to the aircraft power plant, where high temperatures offer a serious obstacle to other products.

Shredded fabric filled plastics:—The fabric filled plastics are noteworthy in their ability to withstand high impact without failure. Fabric filled plastics represent an intermediary stage between molded and laminated plastics, for whereas the whole fabric is used in laminated products, the shredded filler is employed in the molded product. High grade impact resistant molded products have an impact strength ten times that of standard wood flour filled materials. The fabric composition is difficult to mold into complicated shapes because of poor flowing characteristics, making them slightly more expensive than the wood flour types.

Mineral filled plastics:—This group can be divided into several classes depending upon the type of mineral used as a filler. The asbestos heading belongs in this category, but it is a large enough group to warrant a separate discussion. The mineral filled plastics are less easily machined than the groups listed above.

(a) Low friction—Powdered graphite as a filler in the molding composition enables a smooth self lubricated surface to be formed, particularly valuable for bearings. Small insulated bearing surfaces are particularly important in certain aircraft instruments.

(b) Mica—Good electrical properties are obtainable by using powdered mica as a filler. Combining a fibrous filler, finely powdered mica, and a phenolic resin gives a plastic with good electrical and mechanical properties.

(c) Miscellaneous fillers as rock powder, rottenstone, slate powder, china clay, and chalk are other inorganic fillers. Heat resistance and low moisture absorption are characteristic of this group.

The methods of molding urea formaldehyde resins and phenol formaldehyde resins are closely analogous to one another, with the exception that the former requires tight fitting molds. Molding sheets are available in lieu of the molding powders. This method is applicable to molds which are flat and extend over a con-

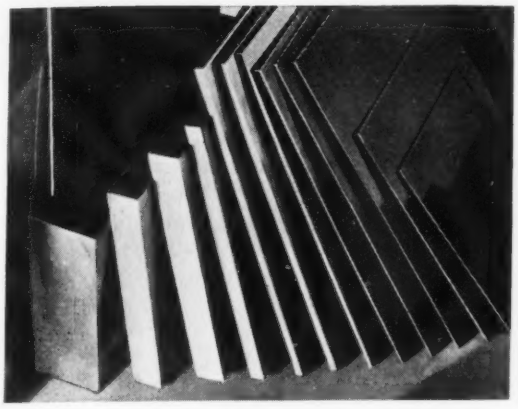


FIG. 2. Sheets of laminated plastic.

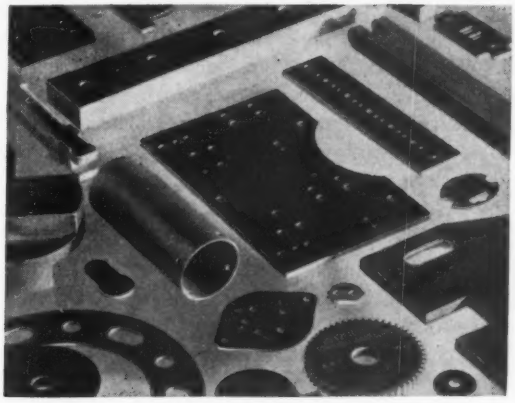


FIG. 3. Fabricated parts of laminated plastic.

siderable area. The molding sheet is brittle, but may be softened at 180 to 200° F., prior to molding. In the softened condition it may be cut,—or in some instances punched into a suitable form for charging the molds.

LAMINATED PLASTIC PARTS

It is hoped that from the above classifications of molded plastic products, it will be possible to select that particular material which will best fulfill the requirements of the intended application. The molded plastics are characterized by accuracy in dimensions, thin walls, bushings, metal inserts, etc. There is an equally important group of plastic materials of laminated structure. These differ from the molded types not only in the method of manufacture, but have superior strength. Using a paper or fabric, with the interweaving of the fibre intact, laminated sheets are piled flat in hydraulic presses, together with the desired impregnating resin, and subjected to high pressures. Phenolic laminated plastics form the greater portion of the laminated products. Rods, tubes, and fabricated parts of all descriptions are manufactured from the laminated stock. As an example of the laminated plastic stocks which are available, attention is invited to the accompanying illustrations of Synthane sheets, rods, and tubes, (see Figs. 2 and 3). From products of this nature appear those materials which have structural importance.

The laminated plastic sheets are useful for panelling, either in the way of decorative effects in cabin airplanes, or else as mounting surfaces for electrical equipment. As the laminated plastics with paper bases exhibit superior electrical characteristics, they are used to a great extent in aircraft electrical systems, in fuse panels, radio panels, coil forms for radio equipment, and terminal boards. The advantages of having available a structural insulating material which can be drilled or tapped to take the electrical terminal connections, are evident in the close spaces alloted for aircraft accessory installation. The plastics maintain their desirable qualities under the extremes of atmospheric conditions encountered by aircraft. The laminated products, as well as the molded products, are resistant to aircraft engine oil and gasoline, are stable, and require no treatment for shrinking, warping, or swelling.

To indicate the range of application of laminated sheet products on modern aircraft, the uses of a canvas base, laminated plastic on a Boeing airplane are tabulated herewith (the parts are machined to size): engine control washers, aileron and other control pulleys, junction box insulator, connector box liner, covers, etc. High shock resistance is exhibited by these products in addition to superior mechanical features. Ball bearing retainers, as for control pulleys, have long been standard upon aircraft.

Laminated plastics may be sawed, sheared, drilled, reamed, blanked, shaved, hobbed, turned, riveted, ground, polished, beveled, and engraved. These machining operations should eliminate any doubt as to the suitability of the laminated plastics for any machining requirement. It is interesting to note in this connection that laminated plastics have been made into gears, which have given long, satisfactory service. Laminated plastics are featured by the absence of noise in gear trains.

In aircraft radio equipment high grade electrical insulators are required for establishing connections from the radio to the antenna, in order to minimize the leakage losses to the aircraft structure. Fairlead bushings of paper base, laminated plastics, are used. In the case of trailing wire antennas for aircraft, a high efficiency of radio transmission can be realized if the fairlead has good electrical characteristics. The fairlead is of a laminated plastic tubing. Laminated tubings are produced in two grades: wrapped and molded. Paper impregnated with resin is wound upon a heated mandrel and undergoes rolling pressure for the 'wrapped' type of tubing. After the operation the mandrel is withdrawn and the tube placed in an oven for curing. The tube is ground to size after curing.

In the molded type, the wrapped paper and impregnation is subject to high pressure in a semi-circular mold. This product is less water absorbent than the other, though it has one weakness in the seam which forms when the molds close together. The seam represents a weak point in the dielectric. The wrapped tube is a more reliable dielectric and should be favored for the radio antenna fairlead on aircraft.

As the molded plastics are grouped in accordance with the type of filler employed, so are the laminated plastics grouped in accordance with the recommendations of the National Manufacturers Association. This list facilitates the selection of the type of laminated plastic to use with a certain job.

(1) Grade X is a paper base, laminated plastic for general use. It has good machining and electrical properties. Up to 1/32 inch thickness may be punched when cold. It is furnished in thicknesses from .010 inch up. Its electrical characteristics are subordinate to the mechanical features. Craft paper is usually used as the base.

(2) Grade XX plastic has low moisture absorption and the best electrical properties under varying climatic conditions. The sheets are .010 inch upwards, and a rag paper base is employed.

(3) Grade XXX has an extremely low moisture absorption. It has a rag paper base and it is furnished in thicknesses from 1/32 inch up. It is harder than either of the two previous grades and fulfills exacting electrical requirements.

(4) Grade XP, paper base, fulfills difficult punching operations on cold stock up to 3/32 inch, and on thicker stocks, depending upon the temperature of the material.

(5) Grade C, canvas base, is characterized by high strength and high impact resistance. It is recommended where high tensile strength and high transverse strength are required. A heavy canvas base is employed.

(6) Grade CE, is similar to grade C, except that the electrical properties are emphasized. The electrical properties are not so good as grade LE, but the strength is superior.

(7) Grade L uses a fine cambric base and is recommended for all applications where a fine machining job and high precision is necessary, such as in fine tooth gears.

(8) Grade LE approximates grade L with high electrical characteristics, and a higher mechanical strength than those exhibited by paper base plastics. A light weight linen fabric is usually used in the base.

There are other bases used for laminated plastics, which have not yet been standardized. Prominent among these are the asbestos fabrics of greater heat and flame resistance.

Cast Plastics

Cast phenolics are similar to the molded type in many respects. Whereas the molded product is favored for the production of large quantities of the product, particularly when there is a need for accurate dimensions, the cast product finds its field of application when the quantity of parts to be supplied is small and there is no strict requirement for accurate dimensions. Cast plastics are noted for their beauty and depth of color and have been promiscuously applied to ornamental jewelry and trimmings, and in the decorative effects of cabin airplanes.

The cast plastics are available in sheets, slabs, tubes, rods, and bars. They machine as easily as brass, involving practically the same tooling. Unlike the molded products, they do not use fillers and they are poured in a sirupy state into molds, where they harden after a period of slow baking. Cast plastics are non-inflammable, have high acid resistance, and good electrical qualities.

The replacement of other materials by plastics in miscellaneous aircraft accessories has been occasioned by one or more of the following claims:

(1) The plastic had a low weight.

(2) The plastic had desirable insulating properties.

(3) The finished product had a permanent finish which would not chip and was resistant to corrosion, erosion, and extreme atmospheric conditions.

(4) There are greater design possibilities with plastics.

(5) The attractiveness of the products could not be duplicated.

(6) The smooth surface insured a low profile drag.

(7) Transparency, non-inflammability, and flexibility.

(8) Low cost.

The Application of Plastics to Aircraft Structures

From the numerous plastic products, suitable materials for aircraft structures may be selected and compared with standard materials. As yet, the application of plastics to structural aircraft parts as wing ribs, struts, sheet stock for stressed skin, etc., is very much in its infancy. Why is it that plastics are considered as aircraft structural materials when they are not within reach of the present duraluminums in strength characteristics? Plastics have a smooth finish essential to low profile drag. They are free from erosion, corrosion, shrinkage, and inflammability, rendering them more lasting than present materials. Plastics have the same strength—weight ratio as woods used in aircraft construction, but unlike woods they are impervious to weather conditions and uniform in physical characteristics. The economy of the plastic construction may be

TABLE 2

Material	Weight, lbs./cu. in.	Tensile Strength, lbs./sq. in.	Compressive Strength, lbs./sq. in.	Modulus of Elastic, lbs./sq. in.	Impact* Strength (Izod)	Water Absorption %-24 hr.	Dielectric Strength Test volts/mil. (Instantaneous)	Maximum Service Temperature, degrees F.	Machine ability
Cellulose Nitrate	0.056 to 0.06	4,000 to 10,000	.....	300,000	10.0 to 11.0	3.0	.....	150	Good
Cellulose Acetate	0.046 to 0.048	4,000 to 6,000	16,000 to 20,000	147,000	3.2	3.0	400 to 800	150—190	Good
Phenol-Molded Wood filler	0.048 to 0.055	6,000 to 11,000	25,000 to 36,000	1,300,000	1 to 3.5	0.2 to 0.6	300 to 500	300	Good
Phenol-Molded Asbestos filler	0.068 to 0.072	5,000 to 10,000	18,000 to 36,000	4,300,000	1.5 to 4.5	.01 to .03	200 to 400	500	Fair
Phenol-Molded Fabric Filler	0.50	6,800 to 7,200	20,000 to 32,000	1,100,000	25 to 30	1.0	200 to 400	300	Good
Urea-Molded Cellulose Filler	.055	4,000 to 10,000	25,000 to 30,000	.....	2.0 to 2.4	1.0	60 to 400	225	Fair
Acrylic Resin (transparent)	.043	7,000 to 10,000	.....	403,000	.....	.17	.....	180	Good
Vinyl Resin (filled)	.054 to .090	6,000 to 7,500	.....	.....	.....	.0	300 to 350	180	Good
Styrol-molded	.038	6,000 to 7,500	.....	.....	.....	.0	500 to 1,000	150	Good
Phenol-lamin., Grade X	.050	12,500	38,000	.....	Good	3.0	500 to 700	300	Fair
Phenol-lamin., Grade XX	.050	8,000	35,000	.....	Good	1.3	500 to 700	300	Fair
Phenol-lamin., Grade XXX	.050	7,000	30,000	.....	Good	1.0	500 to 650	300	Fair
Phenol-lamin., Grade C	.050	10,000	38,000	.....	High	2.0	100 to 150	300	Good
Phenol-lamin., Grade XP	.050	8,000	23,000	.....	Good	4.0	500 to 600	300	Fair
Phenol-lamin., Grade CE	.050	9,500	36,000	.....	High	1.5	350 to 425	300	Fair
Phenol-lamin., Grade L	.050	10,000	37,000	.....	High	1.0	100 to 150	300	Good
Phenol-lamin., Grade LE	.050	9,000	37,000	.....	High	1.2	300 to 500	300	Good
Urea-laminated Paper	.053	8,500 to 9,300	.....	.....	Good	2.1	480 to 600	250	Fair

* Impact Strength — Ft. lbs./sq. in.
Cellulose Derivatives — transparent stock

the deciding factor. In any event, hope has been entertained in some quarters for the appearance of a total plastic airplane.

Attention is invited to Table 2 and the physical properties of the plastic products. A large variety of properties are available, and from this list the aircraft manufacturer may select the ones to fulfill his needs. Whereas greater strength values have been reported from various sources, the values given in Table 2 are representative and have been compiled from reliable sources. The laminated plastics are decidedly superior to the molded products in strength, particularly in compressive strength and impact resistance. The latter property is very important in aircraft construction, as no brittleness can be tolerated. Some of the plastics, such as the cellulose derivatives, become brittle at low temperatures, which should overshadow their beneficial qualities at ordinary temperatures, as the temperature during flight should be the guiding criterion.

The statement that good structural plastics are available, weighing half as much as aluminum, creates more than a transient interest among aircraft manufacturers. For high strength structural members, requiring duraluminum with a tensile strength of 55,000 pounds per square inch, the present plastic products are overshadowed because of their lower strength characteristics. However, for numerous aircraft parts and fittings requiring cast aluminum alloy with a tensile strength up to 30,000 pounds per square inch, the plastic may be considered as a serious rival on a strength to weight basis. The advantages of molded plastics in this respect have already been pointed out. It would be possible to reduce the weight on many parts redundant with metal by substituting plastic parts. The plastics and metals can be combined promiscuously without any fear of electrolytic corrosion between the plastic and the metal. The use of plastic sheets on the fuselage would introduce a product impervious to weather and erosion, at the same time effecting a large saving in weight. On the wing surfaces, the application of the present plastics may be questioned at high wing loadings. As far as ribs, struts, and structural members of the fuselage are concerned, the aircraft industry would feel safer if a higher strength plastic material were developed. The low profile drag of plastic surfaces, high shock absorbing qualities, and resistance to weather and abrasion will keep laminated plastics in the limelight as far as structures are concerned.

It may be that plastics reinforced with wire gauze will exhibit high mechanical strength. The nearest approach to this is the Schwarz method of protecting propellers, described in the beginning of this paper.

Creep: Under rapidly applied stresses, some of the plastics exhibit definite creep tendencies. This is more serious with the unfilled plastics, which while under stress, undergo a slight flow to relieve the strain. This fact has been verified in photoelastic analysis of transparent plastic models.

Fatigue: Very little is known about the fatigue characteristics of plastics, though tests of resilient strips of plastic in fatigue show no evidence of approaching brittleness. Plastics have been satisfactorily applied to elastic mountings undergoing rapid alterations of stress for considerable periods.

Method of Attachment: The plastic materials may be joined to one another by the usual methods of fastening by threaded parts or by riveting. In addition, plastics of the thermoplastic type may be joined to one another by special chemical solvents applied to the edges to be united, and then pressing the parts together.

Stock Sizes: Phenolic castings are stocked in sheet

sizes up to 3x6 feet and thicknesses from 1/16 inch up. Cellulose acetate sheets are available in 20x50 in. in sheet form and from .050 inch up to 1 inch in thickness, and in highly polished, matt, or embossed form. The laminated sheets are usually furnished in 3x3 feet form, with thicknesses ranging from .010 inch up. Rods and tubes of cellulose acetate extend from .050 inch to 2.0 inches in diameter. Rods, tubes, and bars of all sizes are available in the laminated plastics.

It is hoped that from the above discussion, the aircraft manufacturer will recognize the versatility of plastic materials. They are indispensable in numerous aircraft accessories, and as structural members they give promise of future applications. The data given in Tables 1 and 2 and in the description of the fillers for molded and laminated plastics should serve as a guide in the intelligent selection of the most suitable plastic material.

Book Reviews

Airplane and Engine Maintenance, by DANIEL J. BRIMM, JR., and H. EDWARD BOGGESS; Pitman Publishing Corporation, New York; 512 pages, ill., $2.00.

According to the authors this book was prepared with three purposes in mind: first, to serve as a home study course for the student mechanic; second, as an aid to the instructor and student in secondary schools training aviation mechanics; and third, as a reference and handbook for the licensed mechanic.

The authors have succeeded in accomplishing these three purposes in an admirable manner. The book is profusely illustrated with drawings and photographs, and produced by the off-set method. There are five main headings: Aircraft Woodwork, Aircraft Metal Work, Aircraft Fabric Work and Finishing; Rigging, Handling, Maintenance; and Aircraft Power Plants. Also a foreword by Clyde Pangborn, and a preface and introduction.

Much of the material is taken from manufacturers' booklets and handbooks. The collection of such material always presents difficulties, and if there is any criticsm of this book, it is that some of the material included is not the most up-to-date.

The authors are well qualified, as they are both transport pilots, licensed aviation instructors, and have had practical experience in the industry.

C. S. (CASEY) JONES.

Practical Aircraft Stress Analysis, by D. R. ADAMS; Pitman Publishing Corporation, New York; 162 pages, $2.50.

This book is an elementary manual for the stress investigation of conventionally designed aircraft structures. It embodies not only a simple style and clear definitions, but uses the simplest forms of accepted formulae, design data and curves from reputable sources. It is obviously a book for the very practical designer who is not given to ultra-refined calculations but is a handy book for anybody in the drafting room.

The material is divided into five chapters, each of which discusses an essential feature of stress analysis. The first part of the first chapter defines the terms which are used throughout. To American eyes they are somewhat strange, but amply fill the bill, such as "reserve factor" for "factor of safety". Part 2 of this chapter goes into the loads and their application and contains tables and charts from the latest British and N.A.C.A. publications. Every stressed part of the plane is mentioned with adequate information for general design.

Chapter 2 discusses the importance of fittings, giving practical detail and illustrative examples. Welding is discussed as befits its importance. Secondary stresses are omitted.

The strength of beams, struts and ties treated in chapters 3 and 4 is similar in exposition to material in the reference quoted in the bibliography. The analyses are of the simplest kind.

The last chapter on torsion is useful but could be simplified somewhat.

I. B. YASSIN.

Books Received

Twenty-first Annual Report, National Advisory Committee for Aeronautics, Technical Reports 508-541; United States Government Printing Office, Washington, D. C., 1936; 625 pages, $2.75.

The Lilienthal Gesellschaft Meeting in Berlin

With an account of the trip of the Secretary of the Institute to Moscow, Rome, Paris and London

THREE members of the Institute attended the first formal annual meeting of the Lilienthal-Gesellschaft für Luftfahrtforschung* held in Berlin, October 12–15, 1936, as guests of the new German society for aeronautical research. Dr. Clark B. Millikan presented a paper *"On The Results of Aerodynamic Research and Their Application to Aircraft Construction."* Arthur Nutt's paper was on *"Aircraft Engine Design and Operating Problems."* Major Lester D. Gardner, Secretary of the Institute, was also invited to be a guest at the meeting.

The formal sessions opened with a reception and dinner at the Neues Palais, Potsdam. This was the first time that the palace had been used for a formal gathering since the Armistice. Prof. Dr. Carl Bosch, one of the three Presidents of the Lilienthal Society, delivered an address of welcome to the forty foreign delegates and two hundred guests, part of which follows:

"Gentlemen,

"The President and the Senate of the Lilienthal Society for Aviation Research have requested the pleasure of your company, in a smaller circle, before the opening of the General Assembly.

"Especially in view of our foreign guests we have seen fit to approach the Minister President for Prussia as the first personality in the state of Prussia, who is at the same time Reich Minister of Aviation, the Protector of our Society, with the request to put at our disposal a meeting-place doing justice to the occasion. We have to thank his intervention, as well as the kindness of the Administration of Palaces and Gardens of the Prussian State for being able to meet today at a spot where before now events of historically far-reaching importance have taken place.

"The plans for the construction of this beautiful palace were put into effect, immediately after the end of the Seven Years' War, by the great King Frederic II of Prussia, after events which had attacked the foundations of the Prussian State.

"Today, close on to twenty years after the end of the great war, we live in an era where many social and political notions all over the world are altering. With our own eyes we see humanity searching and groping for new ways of life. In our own country we notice the effects of a movement changing our nation from its innermost being.

"The management of our Society has considered it appropriate to conduct the beginning of our scientific and technical discussions from a place famous in German history.

"Gentlemen, may I be permitted to express the great pleasure which has been given us by the fact that the High Command of our aviation has come here this evening, honoring us with its presence. Particularly during the last year, by the formation of the Lilienthal Society and the foundation of the German Academy for Aviation Research, these activities have been offered so many expressions of special confidence from the part of our highest leaders, that they fully appreciate their duty to take part with all their might, by untiring work and the greatest efforts in the realm of spirit and invention, in order to ensure technical progress.

"Famous personalities coming from foreign aviation authorities, foreign scientific organizations, and technical institutions have accepted our invitation. May I here bid you welcome to today's event on behalf of the German research institutes.

Scientific life and technical production are ever connected in their work by mutual ties. It is not only the technical discussions or research and experimental activities undertaken in common which forms the supports of collaboration between the two branches. The personal angle, too, of mutual relations between scientist and practical engineer must continually be enlarged, so that the undefinable but highly important effects of mutual understanding may be developed.

"We are happy to find in this circle leading men from German science, engineering, and economics gathering with leading men of the state and the political movement.

"Knowledge of the principles of science, forming the basis for the progress of civilization, is in point of fact international. The history of engineering again and again shows proof of the fact that fresh findings in one place are repeated somewhere else—generally quite independently of one another. When it comes to the last, only mutual accessibility of experiences appears decisive in determining human progress as a whole. It is a matter of course that the natural interests of man and, later, of an entire people, tend first of all to exploit the knowledge gained to their own ends. It would be a mistake, however, to believe in the possibility of keeping entirely secret for any length of time the complete amount of knowledge reached in a larger and wider field.

"Natural interests, therefore, make it desirable to arrange—with due regard to the special and individual results of certain activities—some exchange of experiences by different scientists, larger organizations, or even the nations themselves, on main basic points.

"The field of aviation engineering has today already become a wide field of action, affecting in a peculiar manner the principles of general engineering. Many of the important discoveries by certain individuals, certain organizations, and certain nations have become general property throughout the technical world.

"The German aviation scientists present regard the friendly-minded exchange of experiences covering such grounds as are familiar to the company gathered here, and at the same time open to general discussion, as being a valuable aid in developing the general progress of human civilization.

"In the foundation decree issued to the German Academy for Aviation Research, the Reich Minister of Aviation has pointed out what fundamental changes, not only with regard to the economic but also to the political structure of the world, result from the development of flying. The Lilienthal Society intends, by this reception, to contribute towards the development of a close relationship on the subject of aviation engineering in this company of noted specialists.

"We are aware of the fact that the fundamental changes which the human spirit can bring about in the development of the nations by new inventions can never emanate from common

* The general purposes and organization of the society were described in the J.Ae.S., August 1936, Vol. 3, No. 10, p. 372.

work in science or engineering. We do, however, believe that the organization of spiritual cooperation will often provide the basis for the employment of fresh knowledge, so that in this manner the development of inner connections between all branches of science and engineering serves the progress of humanity.

"Development of man's life does not depend only on the will and the knowledge of each individual. Elements of nationality and character, economic interests, geographical living conditions, and many other factors go into the determination of the existing state and the further development in the inner structure of humanity.

"The management of the Lilienthal Society has now arranged for a concert to be given by the world-famous conductor Edwin Fischer and his orchestra, who will play for you music by some of the greatest German masters. In these historical and classical surroundings the Society wishes, in the voice of those German masters long dead, yet immortal, to unite the spirit of their guests in striving towards higher values of the inner self and those great qualities which—inaccessible to speculative contemplation—would seem to point towards the common origin of humanity throughout the world."

After the concert in the private theatre of the palace, the guests were given a formal dinner. General Erhard Milch, who is not only in command of the German Air Force but Secretary of State for Air, and an Associate Fellow of the Institute of the Aeronautical Sciences, gave an address of welcome in which he expressed the pleasure of greeting the foreign guests and the hope that the meeting would assist in increasing friendly relations between the countries represented. Major Gardner was requested to reply for the foreign guests.

"It is a great honor as well as a pleasure to respond to the greetings which have been extended to the foreign guests of the Lilienthal-Gesellschaft.

"Those of us who have been in Germany before know the delightful hospitality that we receive whenever we come to Berlin to visit our German aeronautical friends. For all your foreign guests I express our great appreciation and gratitude for the opportunity of meeting with the distinguished officers, scientists and engineers who are members of this society which is already one of the leading aeronautical organizations in the world.

"It is fitting that all countries should honor the memory of that great pioneer, Otto Lilienthal, for it was from him that the world received inspiration in developing the art of flight.

"I am sure I speak for all the foreign guests in expressing my belief that these annual meetings afford a unique opportunity for aeronautical workers from many lands to meet and discuss their mutual problems."

"May I, in closing, express the hope that the future of German aeronautics may be even more brilliant than it has been in the past and the contributions of its aeronautical scientists be so fruitful that the results of such gatherings as this may bring a better understanding between the peoples of our countries and lead to a peaceful solution of some of the problems which are now disturbing the world."

On Tuesday morning, October 13, the technical session was held at the Kroll Opera House in Berlin. Since the burning of the Reichstag building, official meetings of the government have been held here. There were about sixteen hundred scientists and engineers present.

Dr. A. Baeumker, Councillor of the Air Ministry and active President of the Lilienthal Society, gave the address of welcome, part of which follows:

"Gentlemen,

"On behalf of the Lilienthal Society for Aviation Research and the affiliated German research institutions I have the pleasure of welcoming you to the opening of our scientific meeting.

"The Lilienthal Society today makes its first public appearance, by lectures and visits, since its foundation during the spring of this year.

"At the commencement of the meeting the presidents addressed the following telegram to the Protector of the Society:

"To the Minister for Aviation,

Colonel-General Goering.

"The first Scientific General Assembly of the Lilienthal Society in gratitude recalls its Protector.

"In accordance with the directions given by yourself and your Secretary of State the event is held in the spirit of exchange of important technical experiences in German aviation, and in renowned circles abroad which are closely connected with our scientific life.

"The Society begs to be assured of your sponsorship, so valuable for further success, during the coming year."

The Minister has answered in the following words:

"To the Lilienthal Society for Aviation Research, Kroll Opera, Berlin.

"Every success to your Meeting!

"The secret of technical progress lies in the unerring will towards common work in solving the great tasks awaiting us. Therefore you may remain assured of my wholehearted support in the development of close mutual ties between the scientific and technical work of research and industry.

"Please convey my greetings to the guests of your Society.

HERMANN GOERING."

"As the managing President, and on behalf of the Presidents and Senate, I welcome the Secretary of State for Aviation, General Milch, who attends this meeting as the representative of the Reich Minister for Aviation. For more than ten years he has been closely connected with our aviation engineering in a leading position, and in this select circle the men of our world of science and engineering wholeheartedly appreciate his personality. The Society is aware of the fact that he too should be thanked in the first place for the independent and important position of aviation science and engineering in the realm of aviation generally.

"The Society next welcomes with especial cordiality Colonel Udet, Chief of the Technical Bureau in the Reich Ministry of Aviation. A great responsibility rests in his hands. His bureau coordinates all dealings connected with research on technical development, with production, and with technical examination. We are certain that his great experience in producing aeroplanes will be a valuable aid towards developing the necessary scope of work in aviation research in the general field of flying.

"We then welcome many important representatives of the authorities, of military aviation, and of numerous organizations of the National-Socialist movement, as well as all those who by action, word, or letter uphold our Society in public.

"Besides leading collaborators of German aviation science, we have the honor to find in our midst notable exponents of general science, of the aviation industry, and from German economic life.

"With especial pleasure we extend our welcome to the representatives of foreign powers and the foreign scientific and engineering guests who, despite the trouble and difficulties ac-

companying every journey, have not refrained from traveling all the way to Germany.

"The Society is particularly happy to see here, for the purpose of lecturing, two personalities prominent for aviation research in the United States, and who will provide German aviation engineering with experiences and ideas for further development.

"Mr. Arthur Nutt, chief constructor of the Wright Aeronautical Corporation, has achieved world fame by his constructive efforts in the development of high-efficiency aero-engines. His systematic activities and his highly organized cooperation with his fellow workers must be thanked for many items of general value in the design of aero-engines. Quite a number of his aero-engine types are in wide use throughout the whole world. The sales of a new product are a definte indication for the manufacturers' performance: this subject in particular shows up the extraordinary importance of our guest in the strongest light.

"Dr. Clark B. Millikan has become known by his work in connection with the great technical achievements of the American aviation industry. Many close ties of personal and business friendship connect German aviation science with the management and staff of his research institute in beautiful California. There is no need to prove that the methodical cooperation of research and production in California—as well as elsewhere in the United States—is the chief reason for the extraordinary progress of aviation engineering in that country.

"Two well-known personalities from our aeroplane engine industry have been kind enough to promise this assembly two addresses concerning certain important subjects connected with their work, with the assistance of their respective firms.

"Dr. Gasterstädt who, we are very sorry to state, is owing to illness unable to speak, has asked his collaborator, Dipl.-Ing. Gerlach, to read to us his lecture. Dr. Gasterstädt is famous in our aviation engineering and science for many years as one of the creators of the Junkers gas oil engine. As a result of the work achieved on this subject by a small circle of engineers at the Junkers works German aviation is to-day in the fortunate position of being able to organize long-distance air travel over sea and land with the greatest economy and transport safety.

"The Daimler works have during the last few years again proved their ability by many technical advances in automobile construction, as well as notably in aero-engine design. The Daimler-Benz Diesel engine for airships has taken a successful part in developing our relations with the countries of North and South America. Dipl. Ing.-Nallinger will comment on some principles bearing on the design of modern aero-engines.

"At this point, I should like to thank in advance the two speakers visiting us from the United States and the two speakers from the German aviation industry, as well as all those who will give their valuable help in arranging this event.

For a long time leading men in German aviation science have, by their membership in the Institute of the Aeronautical Sciences in New York, been closely connected to American aviation science by an exchange of theoretical knowledge. All visitors from the German aviation engineering industry to the United States have returned home full of gratitude for the kind and far-reaching assistance extended to them by this Institute. It is a very great pleasure indeed for us to see here prominent representatives of this organization which is kindred to our Lilienthal Society, and we venture to hope that this fresh contact may further stimulate the relations between the two institutions and their leaders.

"In the name of the Society I next welcome leading personalities from British aviation, the French Air-Ministry, the French and Greek scientific world, the Italian and Austrian air forces, and specialists from Sweden and Switzerland.

"The organizers hope that this visit from our foreign friends may help to develop even more our scientific and technical connections on the subject of aviation with all the countries here represented, thus making it possible to achieve those common relations which are so necessary for the international progress of human culture and human well-being.

"We would express the hope that our foreign guests, among whom we find, as a friend of German aviation, the editor of a well-known flying magazine (C. G. Grey of *"The Aeroplane"*) may take home with them, besides impressions on German aviation, some ideas on the development of public life in Germany during the course of the last few years. The management of the Society will endeavour to fulfill the wishes of our foreign visitors as far as possible in view of the lack of time.

"It is with great pleasure that we see assembled here, for the first time at a scientific meeting, such a number of students of aviation science from the universities and technical schools. Over a hundred students have responded to the call sent out by the German Institution for Experimental Aviation. Twelve to fifteen years ago the gliding meetings on the Wasserkuppe were decisive for the advance of the generation returning from the war on the subject of aviation engineering. In the name of the Lilienthal Society I venture to hope that in future the Lilienthal Meetings too may help to improve in the same manner the relationship between those working in research institutions and the industry on one hand, and our younger technical generation on the other.

"The members of the Lilienthal Society form a body built up from common work directed towards gaining fresh knowledge. Beside the technical question, the society aims at the formation of a spirit of internal unison. There exist no better means for this than a union of all mental workers in a meeting comprising scientific lectures and visits. The management of the Lilienthal Society thus considers it its duty to develop the internal unity necessary for the progress of work by cultivating human relationships.

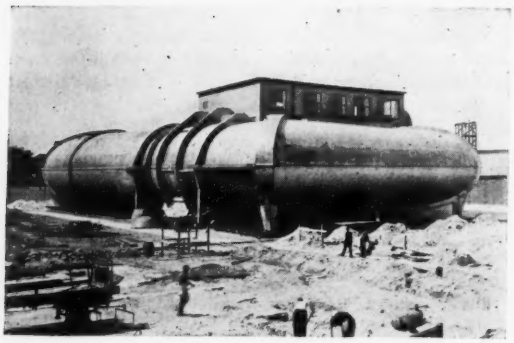
"We hope that the lectures and visits will be able to give something to everyone, in spite of the varied composition of our membership. Where the organization of the event should reveal any failings, we would ask all participants to bear this in patience in view of the fact that the society, having only been founded in June, is still in a stage of construction.

"Professor Prandtl, who is respected by German aviation science and engineering for his highly valuable work as well as for his personality, has kindly consented to take the chair as President of our Society during the following scientific lectures."

Dr. Prandtl, who is an Honorary Fellow of the Institute of the Aeronautical Sciences, then introduced the guest speakers.

The foreign guests were greeted privately by General Herman Goering and General Milch, after which the former delivered a short address of welcome and encouragement to the meeting.

After luncheon, the guests were taken to the new air academy at Berlin-Gatow. This school for officers of the German Air Force gives instruction in technical aeronautics, flying, aircraft armament and aerial tactics and strategy. It is a model of architectural simplicity and taste. Located on the shore of the River Havel it has the advantages of providing for its students air, land and water sports as well as aeronautical instruction.



Exterior view of the full scale wind tunnel of the D. V. L., Adlershof, showing air ducts.

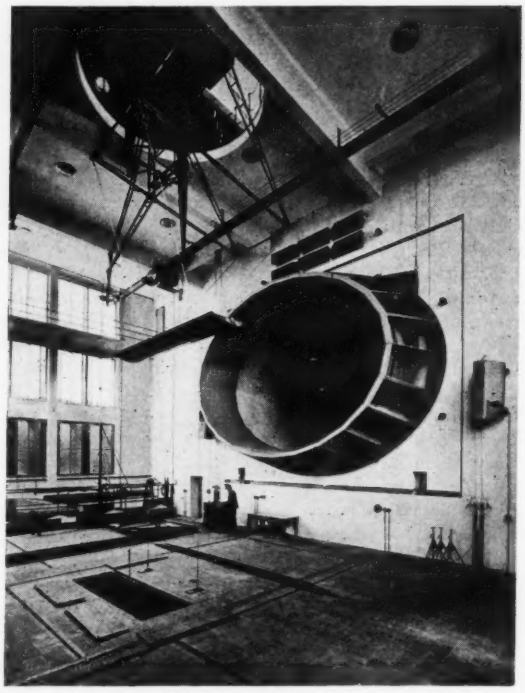
The equipment of the laboratories, wind tunnels, testing apparatus and lecture rooms is probably the most complete and satisfactorily arranged for instruction purposes of any technical school in the world. It had the great advantage of being built at one time, under a single direction, and after a study of all other similar institutions. As the academy had only recently been completed, the guests of the Lilienthal Society were among the first to see the equipment in its complete state. Only a few students are in attendance at the technical Academy at present, but eventually it is hoped that practically all the higher officers of the German Air Force of the future will receive technical training at the Academy. After inspection of the Academy, a collation was served in the large casino or officer's club.

On the following day the guests had the option of visiting the Junkers Works at Dessau or the Aerodynamic Laboratories at Göttingen.

Mr. Nutt went to Dessau and Dr. Millikan and Major Gardner visited Göttingen, as they had previously been there as guests of Dr. Heinrich Koppenberg, Managing Director of the Junkers Works.

The visitors to Dessau saw what is probably the largest factory for the production of aircraft and aircraft engines in the world. The works are scattered among several nearby cities, as the problem of housing over thirty thousand workmen assembled from all parts of Germany was almost as great a problem as the construction of these huge buildings within a year.

Dr. Koppenberg, who was selected to expand the Junkers works after the death of Dr. Junkers, is famous in Germany as a producer of iron, steel and factory buildings. With great and pardonable pride he shows visitors the different buildings, which use production methods similar to those employed in the automobile factories in the United States. The large engine factories at Magdeburg and Kurtin, where the Junkers aircraft engines are made, are models of modern construction. Great villages of worker's homes have been erected and recreational facilities provided for the families.



Full scale wind tunnel of the D. V. L. Testing room with nozzle (5 x 7 m.), model wing and model suspension, and six-component balance.

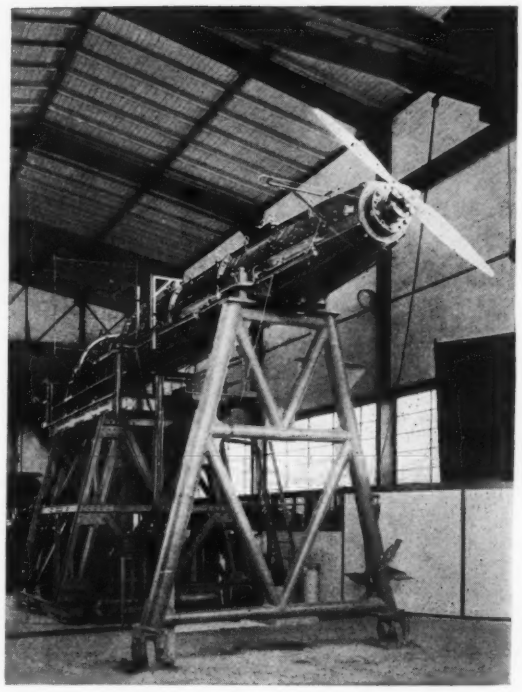
Possibly the most interesting part of the Junkers works to foreign visitors was the Kurtin works where the Junkers heavy oil engines are manufactured. Over four thousand workmen are employed in producing these engines at a rate which is startling.

The visit to Göttingen was of exceptional interest as it was the first time that the new suction and pressure full scale wind tunnel was shown to visitors. The group which was guided by Dr. Prandtl comprised distinguished scientists and engineers from many countries. Dr. Prandtl, assisted by Dr. A. Betz, explained the working of the tunnels, tanks and test apparatus. The aeronautical laboratories have been greatly enlarged and will, when completed, be one of the best equipped research institutes in the world.

The formal meetings were closed by a buffet dinner at the Haus der Flieger, the new home of aviation in Berlin. This building, which is presided over by Wolfgang von Gronau, President of the reorganized Aero Club von Deutschland, is one of the most beautiful and complete clubs of the world. At the suggestion of General Goering, the old Prussian Parliament Building was remodeled into a club with every possible facility for comfort and entertainment.

During the evening Dr. Millikan and Mr. Nutt broadcast to American radio stations.

A special visit to the Deutsche Versuchsanstalt für Luftfahrt at Adlershof, near Berlin, was arranged for



Propeller test stand of the D. V. L. (Capacity 1290 hp., 1200-2200 r.p.m. and 770-420 m.kg.)

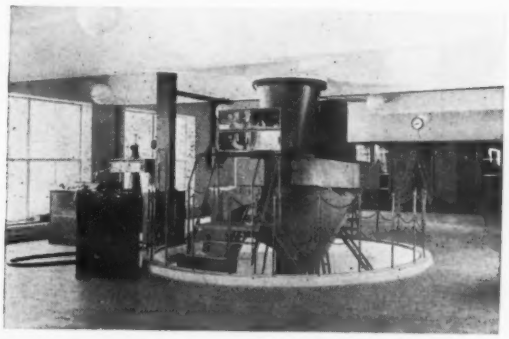
the three American guests. Minister Baeumker and Dr. Seewald, the Director of the laboratories which correspond to our N.A.C.A. laboratories at Langley Field, took the guests on a complete tour of inspection of the new equipment. As all the new installations are housed in modern new buildings and almost all the machinery and apparatus are new, visitors are greatly impressed with the scope of the research work that is undertaken.

Another interesting visit made by the Institute's three delegates was to the Heinkel works at Rostock and Warnemunde. Dr. Heinkel and staff showed the guests several factories, in one of which some interesting wood construction is to be seen. To see five or six hundred drawing boards, all used for design of new types of airplanes at one factory, gives some impression of the extent of German aircraft development.

Other visits were made by the American visitors to the interesting works of Henschel. Here the factory is divided into sections and so arranged as to be comparatively secure from aircraft bombing attack. From the air these huge factories look like monster hangars, staggered around a crescent. Underground rooms are provided for the workmen for shelter during air bombing attack.

Mr. Nutt visited the great motor factories of Siemens in Berlin and B.M.W. at Munich.

The American delegates were unanimous in their appreciation of the courtesy and thoughtfulness of President Baeumker in making such complete arrangements



Full scale wind tunnel of the D. V. L. Recording room with six-component balance, service and recording desk.

for their trips from the United States and return, and his tireless efforts to make sure that every hour of the day and evening were occupied with interesting hospitality. Two box parties were given at the Staats Opera for the foreign guests. Dr. Koppenberg, also, made the trip of the American delegates easier by placing at their disposal Junkers Ju-52 and Ju-86 aircraft. He gave a dinner party in their honor at which many of the leaders of German aviation were present.

After the meeting Dr. Millikan returned to the United States, but Mr. Nutt and Major Gardner visited other European countries.

The trip of Major Gardner was exceptional in many respects. In about thirty days he visited Russia, Germany, Italy, France and England. This was made possible by the courtesy of the Lilienthal Society arranging for him to be a guest on the ninth crossing of the airship Hindenburg. This was done as a recognition of the work of the Institute by the German Air Ministry. As the Hindenburg arrived in Frankfurt a week in advance of the opening of the meeting in Berlin, Major Gardner, through the courtesy of the Deruluft, the German-Russian airline which flies from Berlin to Moscow, continued directly through to the capital of the U.S.S.R. There he was the guest of the United Aircraft Trust. He visited the Central Aero Club of Moscow and was shown its many activities by Commandant Mark Deutsch, who is the Director.

This Aero Club, which is one of the 152 in the Soviet Republic, has 5,000 members, all of whom are active pilots, student pilots, parachute jumpers, glider pilots or undergoing aeronautical instruction of some kind. The members are drawn from the workers in factories, who for especially good work are permitted to engage in aeronautics as a sport. The Central Club has the support of, but is not a part of the "Osaviakhim," the Society of aeronautical propaganda, with over 10,000,000 members. There are over 4,000 parachute jumpers in Moscow and each must pack his or her parachute before jumps.

Over 10,000 pilots are being trained for sport in 1936. The club house, which is a modern club build-

AT GÖTTINGEN

Professor Prandtl with guests. Ministenialrat A. Baeumker (in uniform), President of the Lilienthal Society; Major Gardner, J. J. Ide, H. E. Wimperis, President of the Royal Aeronautical Society; Professor Ph. Theodorides of Athens, Professor Joseph Kampé de Feriet of the University of Lille, France; George P. Douglas of Farnborough, Dr. Clark B. Millikan, A. Fage of the National Physical Laboratory, D. H. Williams of the National Physical Laboratory, England.

ing, is complete in its equipment for social and educational purposes. The flying field of the Club, while still under construction, will be one of the largest in the world when completely drained.

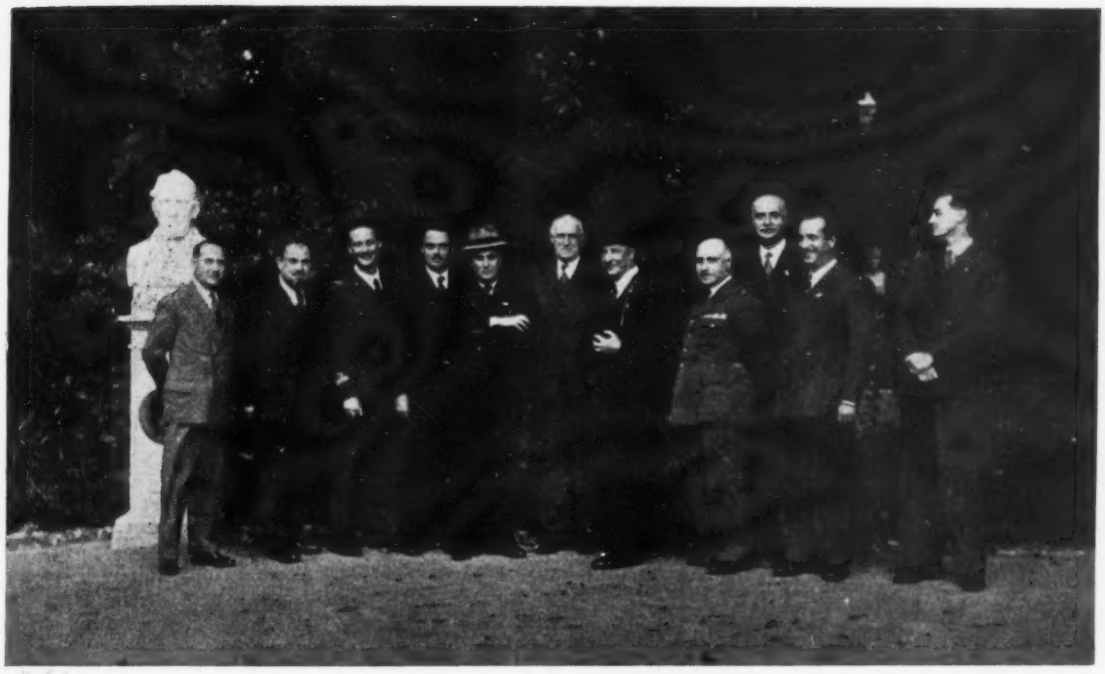
The next morning a visit was arranged to inspect the Central Aero-Hydrodynamic Institute, popularly known as Z.A.G.I., where the Director, Ing. N. M. Kharlamov and Prof. A. O. Nedrossov, showed the Secretary of the Institute of the Aeronautical Sciences the six wind tunnels, the testing laboratories and the divisions for special research in woods, metallurgy, chemistry, etc. The development of new types of aircraft is conducted here under the direction of A. N. Toupoleff from whose initials the famous series of "A.N.T." airplanes receive their designation.

After several hours visiting the laboratories an elaborate luncheon was given for the guest, attended by the heads of the various departments. Any impression of shortage of food, not to say delicacies, in Russia would be dispelled by anyone privileged to enjoy a meal at Z.A.G.I.

In the afternoon, Major Gardner visited the Central Research Institute for Aircraft Motors where B. Stetchkin, the Assistant Director, and Basile Belicov, Chief Engineer of the Testing Department, showed him the experimental laboratories, the test stands, and some of the new carburetors, variable pitch propellers, and superchargers of Russian design. Two of the V-type 1200 hp. engines were being tested and the offer was made to have the horsepower checked in response to a facetious remark. These are the engines which are to be used on the 16 new sixty passenger planes which will be powered by six motors giving 7200 hp.

Later Mr. Toupoleff received Major Gardner and discussed with him the plans for the new Russian airline which is planned to operate between Moscow and the United States. While no final decision had been reached as to whether flying boats of the Martin China Clipper type of land planes equipped with skis were to be used, the impression was given that within a short time completed plans will be disclosed for a route of great international significance. Invitations to visit aircraft factories and engine factories had to be declined as it was necessary to return to Berlin for the opening of the Lilienthal meeting. The flight back in a Russian three-engined commercial air transport was not interrupted as was the outward trip by a stop-over at Weliki Luki, the Russian airport which is gaining fame as the place where travellers by air enjoy a forced night's rest amid the most primitive conveniences.

After the Berlin meeting Major Gardner flew to Rome as a guest of the Deutsche Luft Hansa to visit several Italian members of the Institute and see the marble aeronautical city of Guidonia. His Excellency, General G. A. Crocco, whose name is known all over the world for his contributions to aeronautical science, undertook the courteous role of host and showed with great pride the splendid equipment of this new Italian



LUNCHEON GUESTS AT ROME

His Excellency, General G. A. Crocco, General A. Fiore of the Air Ministry, Raffaele Giocamelli, Editor of L'Aerotechnica; Professor E. Pistolesi of Pisa, A. Oberziner, Professor Antonio Capetti of Turin, Luigi Crocco, Captain Thomas D. White, U.S.A.; and Major Gardner.

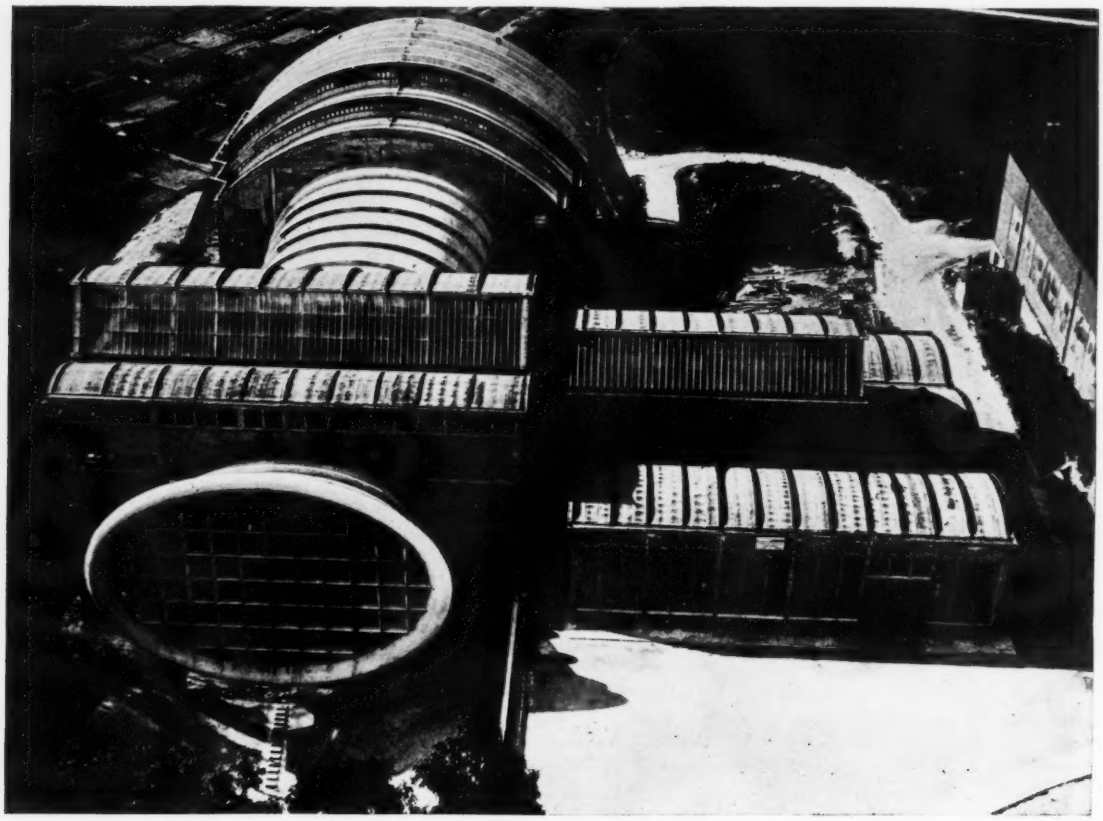
center of aerodynamical research. Those friends in the United States who were privileged to know Col. Guidoni when he was in Washington pass with sad hearts the monument erected on the spot where he was killed.

Guidonia has been described many times but no pictures by word or photograph can convey the impression of the luxurious surroundings which have been provided for the aeronautical specialists. Every form of equipment is available and the display of every kind of aeronautical instrument and apparatus of foreign and Italian origin is bewildering. The battery of four large wind tunnels in one group is most impressive, while the super-sonic high speed tunnel is probably unique in the world. The large towing tank is not only excellent from a hydrodynamic standpoint but is decorated as tastefully as the other parts of the buildings. A large full scale double return wind tunnel is nearing completion as is a vertical spinning tunnel. The new full scale tunnel is set apart from the other buildings and decorated with delicate shades of blue so that it has not only utility but beauty as well.

After the visit to Guidonia the Italian Aeronautical Engineering Society gave a luncheon in honor of the Secretary of the Institute. Fifteen of the leading aeronautical scientists and engineers of Italy were present and the work of the Institute was highly praised.

In Paris, M. Fernand Lioré, Honorary President of the Chambre Syndicale, which is composed of the leading aircraft constructors, invited a distinguished group of French aeronautical specialists to a luncheon at the Aero Club de France for the Secretary. Among those present were André Wateau, President of the Aero Club de France; General Albert Caquot, Gustave Delage, Paul Tissandier, Michel Wibault, Pierre E. Mercier, C. R. Waseige, Prof. D. Riabouchinsky, General Grard, Henry Potez, Robert C. Morane, J. Sabatier, E. Dewoitine, E. Benoit, Dr. A. Lapresle, Rene Caudron, Prof. J. Kampé de Fériet, Henri Bouche, J. J. Ide and Commander James Shoemaker. M. Lioré, in a most gracious address, paid a tribute to the work of the Institute and expressed the appreciation of those present for the privilege of association with their American colleagues in the aeronautical sciences. Major Gardner replied with greetings from the Institute and the gratification of members of the Institute in having such a distinguished membership in France.

Through the courtesy of the Air Ministry, M. Wibault took Major Gardner to Villacoublay, the testing aerodrome for French aircraft. He was shown many of the latest types of French aircraft. From there he was taken to Chalais-Meudon, where the large full scale wind tunnel of the Air Ministry is located. This tunnel is unique in that it is open to the air at both ends and the air drawn out by six huge propellers, each driven by a 1000 hp. motor. While the throat of the tunnel is no wider than others in existence it gives an impression of being much larger owing to the large



The full scale wind tunnel of Chalais-Meudon.

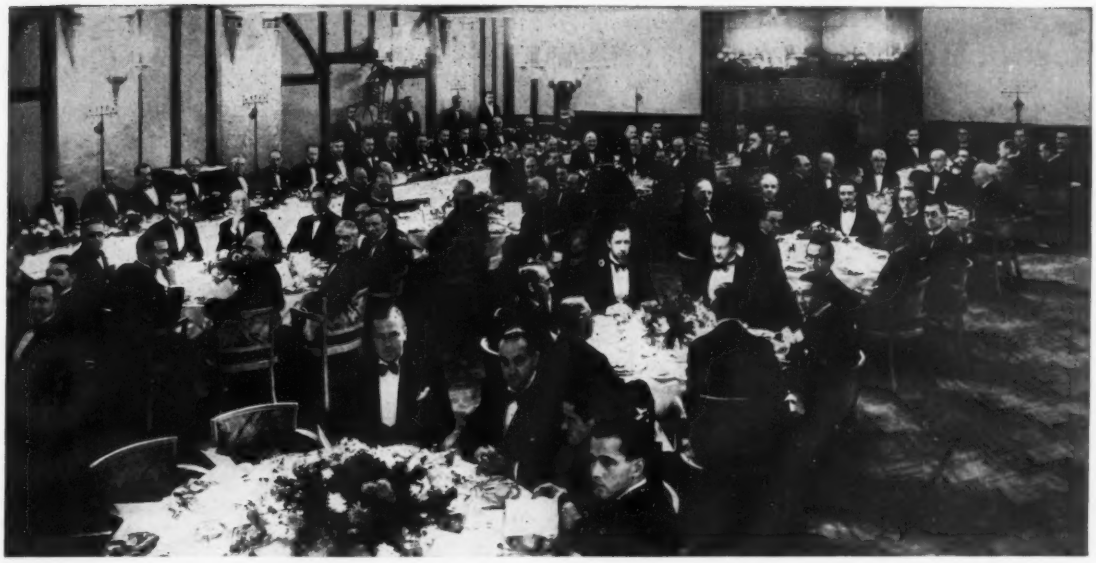
open ends. (See above photograph).

At the end of this hurried trip, Major Gardner spent four days in London. The Royal Aeronautical Society, The Royal Aero Club and the Society of British Aircraft Constructors gave a dinner to him at the Park Lane Hotel on October 28. Sir Robert McLean, President of the S.B.A.C., presided. After a toast to the King and the President of the United States, he, Mr. W. Lindsay Everard, President of the Royal Aero Club and Member of Parliament, and Mr. H. E. Wimperis, President of the Royal Aeronautical Society, made appreciative addresses of welcome to their guest. Major Gardner, after conveying the greeting of the Institute, gave some of his impressions of European aviation and concluded with a discussion of the question "Where is Europe Going?". He said that in his opinion if the vast expansion of air power continued and was used in a general conflict that the only possible result would be annihilation of much development which had taken centuries to create. He expressed the hope that those who controlled the destinies of Europe would come to realize the great destructive power at their command and use this as a means of bringing out a peaceful solution of the problems confronting the various chancelleries of Europe. He also called attention to the new soldiers of the air which were being used by several countries to defend positions which had been surrendered or evacuated behind the front lines after an air attack. He said that this was one of the most significant changes he had observed on his trip and might have an important effect on air tactics of the future. In concluding he proposed a toast to the three organizations which had in such an unprecedented manner honored the Secretary of the Institute.

After the guest of the evening had spoken the Chairman called on T. P. Wright, S. Paul Johnston and James B. Taylor, who were present, for short speeches.

Visits to Farnborough and the National Physical Laboratory were made during which the equipment and research work were described and shown with particularly great courtesy. George E. Woods Humphery took Major Gardner for a flight in one of the new Empire flying boats, of which twenty-eight are being constructed at the Short Brothers factory at Rochester. It took off in 17 seconds and flew at a speed of nearly two hundred miles an hour. Next Spring, a service between New York and Bermuda will be started in cooperation with the Pan American Airways.

As a final courtesy Viscount Swinton, British Secretary of State for Air, invited Major Gardner to lunch at his home with Air Chief Marshall Sir Edward L. Ellington and Sir Francis Shelmerdine, Director of Civil Aviation, after which he was privileged to hear the debate in the House of Lords on the "Shadow



Dinner given to Major Lester D. Gardner by the Royal Aeronautical Society, The Royal Aero Club, and the Society of British Aircraft Constructors.

Industry Scheme" for the construction of aircraft engines. He was accompanied on this interesting visit by S. Paul Johnston, Editor of "Aviation." After the debate they had tea with Lord Swinton, Lord Strabolgi, Lord Sempill, Lord Austin, and Gordon England.

Among those present at the Dinner given by the three Societies were Lord Gorrell, Capt. the Rt. Hon. F. E. Guest, former Air Minister; Air Marshall Sir Hugh C. T. Dowding, Lt. Col. Sir Francis C. Shelmerdine, Air Marshall Sir John F. A. Higgins, Sir Alliot Verdon Roe, J. T. C. Moore-Brabazon, late President of the R.Ae.S.; R. C. Fairey, Herbert J. Thomas, F. S. Spriggs, P. D. Acland, Prof. L. Bairstow, Commander James Bird, Robert Blackburn, Major H. G. Brackley, Griffith Brewer, J. S. Buchanan, Major G. P. Bulman, Col. H. Burchall, R. S. Capon, Allan E. L. Charlton, J. de la Cierva, Dr. H. Roxbee Cox, Lt. Col. M. O. Darby, S. A. Dismore, E. C. Gordon England, A. Fage, A. H. R. Fedden, Lt. Col. L. F. R. Fell, H. P. Folland, H. R. Gillman, A. Gouge, Major F. M. Green, C. G. Grey, A. H. Hall, D. H. Handover, H. Heming, Prof. T. T. Hill, J. E. Hodgson, B. R. S. Jones, D. H. Kennedy, Henry Knowler, G. V. Lachmann, Capt. A. G. Lamplugh, E. B. Lawson, D. Longden, T. B. Macauley, Captain Norman MacMillan, Capt. Ivor H. McClure, Sir Robert McLean, W. O. Manning, Major R. H. Mayo, R. Mitchell, F. Murdoch, J. L. Nayler, N. S. Norway, Lt. Col. M. O'Gorman, F. Handley Page, Harold Pemberton, Commander Harold E. Perrin, R. K. Pierson, Prof. A. J. S. Pippard, D. R. Pobjoy, C. M. Poulsen, C. O. Powis, Capt. J. Laurence Pritchard, D. R. Pye, F. A. Roberts, W. G. Rootes, Lt. Col. M. F. Scanlon, Lord Sempill, E. C. Shepherd, Oswald Short, O. E. Simmonds, Prof. R. V. Southwell, Flt. Lt. C. S. Staniland, Lt. Commander L. C. Stevens, B. Stevenson, Major Oliver Stewart, J. Stubbs-Walker, James B. Taylor, Jr., Frederick M. Thomas, H. J. Thomas, Capt. Grattan Thompson, Dr. A. P. Thurston, Mr. A. Hessell Tiltman, Dr. H. C. H. Townend, Major C. C. Turner, G. R. Volkert, C. C. Walker, Ronald Walker, R. S. Walker, Dr. Henry C. Watts, Capt. G. S. Wilkinson, H. E. Wimperis, Lawrence Arthur Wingfield, Sq. Ldr. Maurice E. A. Wright, T. P. Wright and R. T. Youngman.

The Secretary of the Institute has asked that special mention be made of the exceptional kindnesses he was shown while in Berlin by Major T. J. Koenig, Assistant Military Attaché for Air at the American Embassy, H. Schwencke and Walter Wendland of the German Air Ministry, and A. Boes of the Junkers Werke. In Rome he feels especially indebted to General Bartolucci, Capt. Thomas D. White, Assistant Military Attaché and Mr. Lewis Wickersham of the American Embassy. In Paris, J. J. Ide of the N.A.C.A. and Commander James Shoemaker were especially kind in making arrangements for Major Gardner's visit. In London, Lt. Col. Martin F. Scanlon, Military Attaché for Air, and Lt. Commander L. C. Stevens, Assistant Naval Attaché of the American Embassy, were of great assistance. To Captain J. Laurence Pritchard, Secretary of the Royal Aeronautical Society, Commander Harold E. Perrin, Secretary of the Royal Aero Club, and H. R. Gillman, Secretary of the Society of British Aircraft Constructors, are due the appreciation of the Institute for their courtesy and helpfulness to their fellow Secretary.

Effect of Roughness on the Friction Coefficient of a Closed Channel

V. J. SKOGLUND, *Yale University*

(Received October 6, 1936)

THIS paper presents the results of one series of tests included in a comprehensive program of research on hydraulic friction and roughness being carried on at the University of California. An investigation was made of the friction coefficients of closed rectangular channels having the same absolute roughness. The walls of the channels were made of smooth brass artificially roughened by sixty degree V-grooves transverse to the direction of flow. The effect of relative roughness on skin friction is important in the extrapolation of experimental results on models to the prototype. At present Nikuradse's equation based on data of the pressure drop in pipes artificially roughened with sand is used for this purpose. The results of these tests provide data to justify this procedure.

The friction coefficients of four channels having hydraulic radii ranging from 0.030 to 0.230 feet were determined for different rates of flow. The channels were constructed of two brass plates one-quarter inch by five and three-quarters inches by eight feet and spacers one-sixteenth, one-eighth, one-quarter, and one-half inch wide. Both plates and spacers were roughened their full length by the grooves machined 0.060 inches apart with an average depth of 0.0125 inches. Practically, the absolute roughness of the different channels was the same since the relative width of the plates, which were the same in all, was large compared to that of the spacers. The large aspect ratio of the channel also insured nearly two-dimensional flow. The plates were held in place by heavy iron castings running the full length of the channel. Fig. 1 is an end view of the assembled channel. Five piezometer holes were located nineteen and one-half inches apart along the center-line of one plate. Pressure drops were measured between adjacent holes with vertical or inclined, mercury or carbon-tetrachloride manometers. The results given are for the downstream pair of taps only, pressure drops farther upstream being appreciably affected by entrance conditions. Rates of flow were measured either by an orifice calibrated in place or by direct weighting. A second series of tests were made on the one-eighth, one-quarter, and one-half inch set-ups after the original one had been dismantled, and the results checked with those of the first series.

In the turbulent region where the friction coefficient for rough surfaces does not depend on Reynold's number, a function, containing two empirical constants,

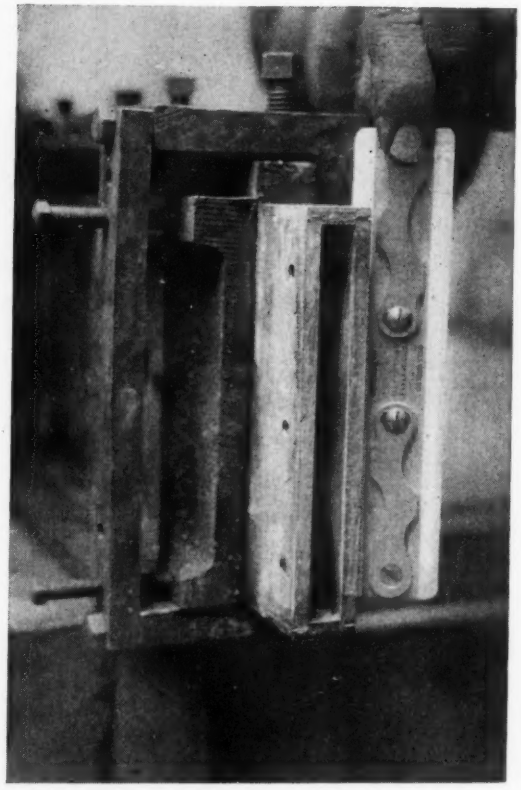


FIG. 1. End view of roughness channel showing brass roughness plates and cast iron supporting frame.

relating it to the relative roughness can be derived by a consideration of the mechanism of turbulence.[1, 2] The function has the form:

$$\frac{1}{\sqrt{f}} = a \log \frac{2m}{\epsilon} + b \tag{1}$$

where:

$$f = \frac{h}{\frac{L}{4m} \times \frac{u^2}{2g}} \tag{2}$$

[1] Th. von Karman, *Some Aspects of the Turbulence Problem*, Proc. Fourth Int. Congress of Applied Mechanics, Cambridge, 1934, pages 54–91. Some *Aspects of the Turbulence Problem*, Mec. Engrg., July 1935, pages 407-412. *Turbulence and Skin Friction*, J. Aero. Sci., Jan. 1934.

[2] L. Pradtl, *Mechanics of Viscous Fluids*, Aerodynamic Theory, Vol. III, Section G, Julius Springer, Berlin 1935, page 47.

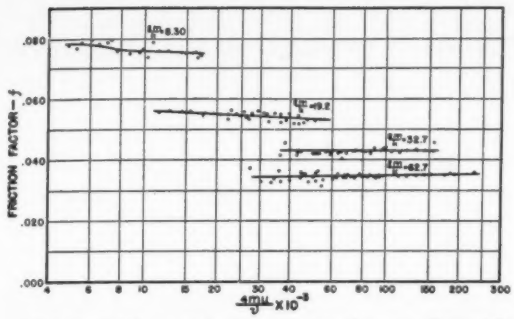


FIG. 2. Friction factor as a function of Reynold's Number.

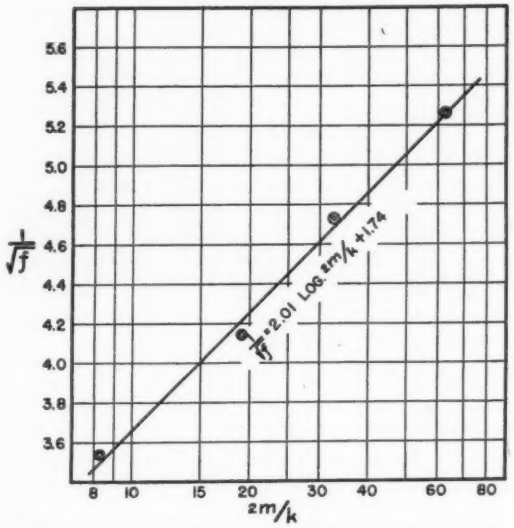


FIG. 3. Friction factor as a function of relative roughness based on equivalent sand size.

f is the friction coefficient.
h is the head loss in feet of the fluid flowing.
l is the length of the channel in feet.
u is the mean velocity in feet per second.
g is the acceleration of gravity in feet per second squared.
m is the hydraulic radius in feet.
ϵ is the absolute roughness in feet.

$$a = \frac{2.306}{2\sqrt{2}} \frac{1}{K} \tag{3}$$

K is von Karman's universal constant characterizing turbulent interchange in a homogeneous fluid.
b is a constant.

From his data on artificially roughened pipes, Nikuradse evaluated the constants a and b using the sand grain diameter k for the absolute roughness. His equation with a change of symbols is [3]

$$\frac{1}{\sqrt{f}} = 2.00 \log_{10} \frac{2m}{k} + 1.74 \tag{4}$$

Since the absolute roughness was constant in these tests, it follows from Eq. (1).

$$\frac{1}{\sqrt{f}} = a \log 2m + d \tag{5}$$

If $a \simeq 2.0$, combining Eqs. (4) and (5), the equivalent sand grain diameter is

$$k = \text{anti log} \frac{1}{a} (1.74 - d) \tag{6}$$

Fig. 2, showing experimental values of f as a function of Reynolds' number, summarizes the data of the present tests. Average values of f for large Reynolds' number plotted as a function of log $2m$ indicated a straight line variation. The constants a and d were then computed for the line having the minimum mean square deviation of the plotted points. The value of a was 2.01 as compared to 2.00 found by Nikuradse. The corresponding value of K for a=2.00 is 0.408. From Eq. (6), the equivalent diameter of sand grains, k, was found to be 0.00061 feet. For comparison, the groove depth was 0.00104 feet. Fig. 3 gives the average values of f plotted as a function of log $(2m/k)$. The probable error of these values was less than one-half per cent.

In accordance with the theory, the agreement of the values of a for the two radically different kinds of roughness used in these tests and by Nikuradse indicates that it will be nearly the same for all kinds of roughness.[4] The equivalent diameter of sand grains is not recommended as a scale of absolute roughness due to difficulties of producing identical surfaces but was used here for a direct comparison of the present results with those of Nikuradse. These experimental data indicate the applicability to artificially roughened surfaces of equations similar in form to that of Nikuradse. The friction factor for fully developed turbulence can be predicted with reasonable accuracy for rough surfaces in any size closed channel from measurements on one given channel size having identical absolute roughness.

[3] Nikuradse, *Stromungsgestze in rauhen Robren*, Forhungsheft 361, July-Aug. 1935.
[4] H. Schlichting, *Experimentelle Unterschungen zum Rauhigkeits-problem*, Ingenieur-Archiv, Bd. VII, Feb. 1936, pages 1-34.

The Nature of Wing Flutter as Revealed Through Its Vibrational Frequencies

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Introduction

ALTHOUGH the problem of wing flutter has been attacked by a number of investigators during the last ten years, their investigations were concentrated on the critical wind velocities and on the effect of the setting angle of the wing, the problem of vibrational frequencies having apparently escaped their attention. While Schlippe[1] systematically studied the vibrational frequencies of a wing at different wind velocities by determining the resonance conditions in forced vibrations, attention[2, 3] had also been attracted to the importance of these vibrational frequencies as revealing the true nature of wing flutter. Since the nature of the flutter thus revealed in a few particular cases has already been published, the present paper inquires into the probable existence of phenomena of the same nature in general.

Although the phenomenon of wing flutter is generally recognized as one of dynamical instability, there appears however to be still some doubt as to whether the large vibrations of a wing at a certain flying speed is invariably due to instability or whether in some cases they are not due to other causes, such as resonance, for example. The present investigation shows that, in the upper half of every range of wind velocities at which the wing flutters in the experiments, resonance forced vibrations of selective type prevail.

With a view to determining the nature of the flutter as accurately as possible, analytical experiments were made, using a model so simple that the elements of that model in vibration were reduced to such an extent that a quantitative calculation for predicting the flutter could be made beforehand. Fig. 1 gives a general view of the device used in the present study, by means of which experiments with any type of vibrations, whether of the type of deflection-aileron, torsion-aileron, deflection-torsion, or even of deflection-torsion-aileron, could be conducted.

All the aerodynamic characteristics of the models were studied statically in a wind tunnel, while the moments

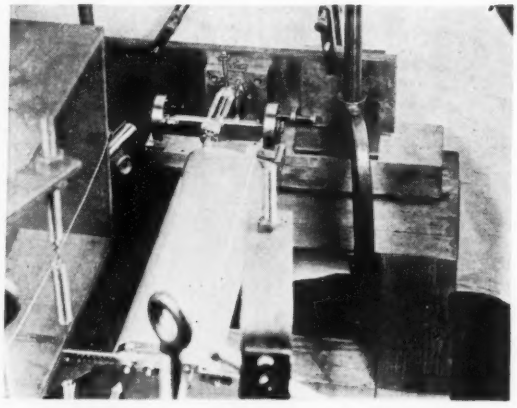

FIG. 1.

of inertia, the elastic stiffness, and the damping coefficients of the wing about the different axes were observed by means of preliminary experiments, the detailed results of which, however, are omitted here.

Not only vibration frequencies, but also vibration amplitudes of wing deflection and of wing torsion were observed at the same time by using different recording cameras, whereas the aileron amplitude and phase referred wing deflection as well as wing torsion were observed by means of a 16 mm. cinematograph. For every condition of wing model, the experiment for ternary coupled vibrations, those for three cases of binary coupled vibrations, namely, wing torsion-aileron, wing deflection-aileron, and wing deflection-torsion; and those for three cases of uncoupled unitary vibrations, namely, wing torsion, wing deflection, and aileron, were made for wind velocities within as well as without the range of the flutter state.

Mathematical Theory of Free Flutter

Treatment of the ternary vibration being very complex, the case of binary vibrations alone will be described. Since the main wing is not deformable in the present condition of the model, the equations for the coupled vibrations are relatively simple, assuming the forms

$$\left.\begin{aligned} a_{11}\ddot{\alpha}+b_{11}\dot{\alpha}+c_{11}\alpha+a_{12}\ddot{\sigma}+b_{12}\dot{\sigma}+c_{12}\sigma=0,\\ a_{21}\ddot{\alpha}+b_{21}\dot{\alpha}+c_{21}\alpha+a_{22}\ddot{\sigma}+b_{22}\dot{\sigma}+c_{22}\sigma=0, \end{aligned}\right\} \quad (1)$$

[1] B. v. Schlippe, *Zur Frage der selbsterregten Flügelschwingungen*, Luftfahrtforschung, Bd. 13 (1936), S. 41-45.

[2] K. Sezawa and S. Kubo, *Nature of the Torsion-Aileron Flutter of a Wing as Revealed by Analytical Experiments*, Rep. Aeron. Res. Inst., No. 136 (Feb. 1936).

[3] K. Sezawa and S. Kubo, *The Nature of the Deflection-Aileron Flutter of a Wing as Revealed by Its Vibrational Frequencies*, Rep. Aeron. Res. Inst., No. 140 (June, 1936).

the details with respect to $a_{11}, b_{11}, \ldots . c_{22}$ being omitted. α, σ are angular displacements of the respective components of the binary vibrations under consideration, namely, wing torsion and aileron displacement, or wing deflection and aileron displacement, or wing deflection and wing torsion. The solution of Eq. (1) should be of the forms

$$\left.\begin{aligned}\alpha &= k_{11}e^{\lambda_1 t} + k_{12}e^{\lambda_2 t} + k_{13}e^{\lambda_3 t} + k_{14}e^{\lambda_4 t},\\ \sigma &= k_{21}e^{\lambda_1 t} + k_{22}e^{\lambda_2 t} + k_{23}e^{\lambda_3 t} + k_{24}e^{\lambda_4 t}.\end{aligned}\right\} \quad (2)$$

From Eqs. (1) and (2) it is possible to obtain a frequency equation of the type

$$A_0\lambda^4 + A_1\lambda^3 + A_2\lambda^2 + A_3\lambda + A_4 = 0 \quad (3)$$

In the problem now under consideration, particularly, λ_1, λ_2, λ_3, λ_4 are generally of types

$$\lambda_1, \lambda_2 = \xi \pm pi,\ \lambda_3, \lambda_4 = \eta \pm qi, \quad (4)$$

but not in their real forms, so that it is possible to write

$$\left.\begin{aligned}\overset{\Delta}{A_0}{}^3 &= 4\,\xi\eta\left\{(\xi+\eta)^2 + (p+q)^2\right\}\left\{(\xi+\eta)^2 + (p-q)^2\right\},\\ 2(\xi+\eta) &= -A_1/A_0,\end{aligned}\right\} \quad (5)$$

Δ being $A_1A_2A_3 - A_0A_3^2 - A_4A_1^2$, from which the following conditions result. Let $|\xi| < |\eta|$ and $A_0 > 0$. (i) If $A_1 > 0$, $\Delta > 0$, then $\xi < 0$, $\eta < 0$, both oscillations corresponding to $\lambda = \xi \pm pi$, $\lambda = \eta \pm qi$ being thus stable. (ii) If $A_1 > 0$, $\Delta < 0$, then $\xi > 0$, $\eta < 0$, the oscillation corresponding to $\lambda = \xi \pm pi$ being unstable and that corresponding to $\lambda = \eta \pm qi$ being stable. (iii) If $A_1 < 0$, $\Delta < 0$, then $\xi < 0$, $\eta > 0$, the oscillation corresponding to $\lambda = \xi \pm pi$ being stable and that corresponding to $\lambda = \eta \pm qi$ being unstable. (iv) If $A_1 < 0$, $\Delta > 0$, then $\xi > 0$, $\eta > 0$, both oscillations corresponding to $\lambda = \xi \pm pi$, $\lambda = \eta \pm qi$ being unstable. The cases that arise most frequently are (i) and (ii), showing that the oscillation corresponding to $\lambda = \xi \pm pi$ alone becomes unstable even in flutter condition.

The frequencies of coupled natural vibrations should be p and q, their values, besides the damping coefficients, being found from Eqs. (3) and (4) such that

$$\left.\begin{aligned}2(\xi+\eta) &= -A_1/A_0,\\ \xi^2 + p^2 + 4\,\xi\eta + \eta^2 + q^2 &= A_2/A_0,\\ 2\xi(\eta^2+q^2) + 2\eta(\xi^2+p^2) &= -A_3/A_0,\\ (\xi^2+p^2)(\eta^2+q^2) &= A_4/A_0.\end{aligned}\right\} \quad (6)$$

The solutions of these equations were obtained by the method of trial and error for any wind velocity within as well as without the range of flutter condition of the wing. In the critical state where ξ tends to zero, $p^2 = A_3/A_1$.

The ratio of the amplitudes of both displacements in each component of the natural coupled vibrations is obtained as follows:

Writing

$$\alpha = M_1 e^{(u+iv)t}, \quad \sigma = M_2 e^{(u+iv)t}, \quad (7)$$

where u, v are real, and substituting them in any equation of Eqs. (1), one obtains

$$\frac{M_2}{M_1} = \frac{Q + iR}{P}, \quad (8)$$

where

$$\left.\begin{aligned}P &= \left\{a_{12}(u^2-v^2) + b_{12}u + c_{12}\right\}^2 + \left\{2a_{12}uv + b_{12}v\right\}^2,\\ Q &= -\left\{a_{11}(u^2-v^2) + b_{11}u + c_{11}\right\}\left\{a_{12}(u^2-v^2) + b_{12}u + c_{12}\right\}\\ &\quad -\left\{2a_{11}uv - b_{11}v\right\}\left\{2a_{12}uv + b_{12}v\right\},\\ R &= \left\{a_{11}(u^2-v^2) + b_{11}u + c_{11}\right\}\left\{2a_{12}uv + b_{12}v\right\}\\ &\quad -\left\{a_{12}(u^2-v^2) + b_{12}u + c_{12}\right\}\left\{2a_{11}uv + b_{11}v\right\}.\end{aligned}\right\} \quad (9)$$

In these equations one should put $u = \xi$, $v = p$ or $u = \eta$, $v = q$ corresponding to the equation denoted by $\lambda = \xi \pm pi$ or $\lambda = \eta \pm qi$. Thus upon extracting the real parts in Eq. (7) and assuming that the initial value of the coefficient of the harmonic factor in α is unity, one obtains

$$\left.\begin{aligned}\alpha &= e^{ut}\cos(vt + \gamma),\\ \sigma &= \frac{\sqrt{Q^2+R^2}}{P}e^{ut}\cos\left(vt + \gamma + \tan^{-1}\frac{R}{Q}\right)\end{aligned}\right\} \quad (10)$$

γ being the initial phase angle for α.

Mathematical Theory of Forced Flutter

In the foregoing section, the flutter, under the assumption that there is no periodic external force of any kind, was treated as an unstable condition of the free oscillation of a wing. If however external forces

$$F_1 = \sum_m f_m\cos(p_m t + \epsilon_m),\ F_2 = -\sum_n f_n\cos(p_n t + \epsilon_n) \quad (11)$$

are exerted in the directions of the α- and σ-movements, respectively, then the equations in Eqs. (1) are replaced by

$$\left.\begin{aligned}a_{11}\ddot{\alpha} + b_{11}\dot{\alpha} + c_{11}\alpha + a_{12}\ddot{\sigma} + b_{12}\dot{\sigma} + c_{12}\sigma &= \sum_m f_m\cos(p_m t + \epsilon_m),\\ a_{21}\ddot{\alpha} + b_{21}\dot{\alpha} + c_{21}\alpha + a_{22}\ddot{\sigma} + b_{22}\sigma + c_{22}\sigma &= -\sum_n f_n\cos(p_n t + \epsilon_n).\end{aligned}\right\} \quad (12)$$

To solve these equations write

$$\left.\begin{aligned}\alpha &= (a_{22}D^2 + b_{22}D + c_{22})U_1 + (a_{12}D^2 + b_{12}D + c_{12})U_2,\\ -\sigma &= (a_{21}D^2 + b_{21}D + c_{21})U_1 + (a_{11}D^2 + b_{11}D + c_{11})U_2,\end{aligned}\right\} \quad (13)$$

D being the operator with respect to t. Substituting these in Eqs. (12) one finally obtains

$$\left.\begin{aligned}U_1 &= U_0 + \sum_m \frac{f_m\cos\left\{p_m t + \epsilon_m - \tan^{-1}\frac{p_m(p_m^2A_1 - A_3)}{p_m^4A_0 - p_m^2A_2 + A_4}\right\}}{\sqrt{(p_m^4A_0 - p_m^2A_2 + A_4)^2 + p_m^2(p_m^2A_1 - A_3)^2}},\\ U_2 &= U_0' + \sum_n \frac{f_n\cos\left\{p_n t + \epsilon_n - \tan^{-1}\frac{p_n(p_n^2A_1 - A_3)}{p_n^4A_0 - p_n^2A_2 + A_4}\right\}}{\sqrt{(p_n^4A_0 - p_n^2A_2 + A_4)^2 + p_n^2(p_n^2A_1 - A_3)^2}},\end{aligned}\right\} \quad (14)$$

where U_0, U_0' represent the terms due to the free oscillation. The solutions of α and σ are obtained by the operation of U_1, U_2 as shown in Eqs. (13).

Now, it is clear that the denominator of the expressions for α, σ have the common factor

$$\sqrt{(p_s^4A_0 - p_s^2A_2 + A_4)^2 + p_s^2(p_s^2A_1 - A_3)^2} \quad (15)$$

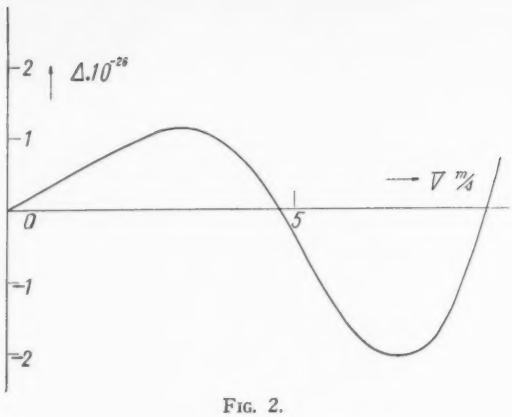

FIG. 2.

Therefore, should frequency p_s of the forced vibrations approach the frequency at the criticals of free flutter, the second as well as the first terms under the root sign in Eq. (15) simultaneously vanish. Thus, even should the forces f_m or f_n be very small, the values of α and σ would tend to assume infinitely large values under resonance conditions—a condition never met with in other dynamical problems.

It is possible to obtain the ratio of the amplitude of σ to that of α for a particular p_m (or p_n) from Eqs. (13) and (14). It is evident that, under resonance conditions for any wind velocity, the vibrations assume the type of free oscillation, the ratio of the amplitude of σ to that of α and the phase difference between the two being respectively the same as those of free oscillation.

Since the case of ternary flutter when treated in the same way as in the present one is fairly complex for free as well as for forced flutters, its theory will not be discussed in the present paper.

AN EXAMPLE OF AN EXPERIMENTAL RESULT FOR A BINARY FLUTTER

As to the models for experiments, the one that will be discussed in the present section is of symmetrical profile, namely Göttingen 459, the mass including lever fittings, span, chord, and aileron chord being 274 gm., 35 cm., 8.5 cm., and 1.2 cm. respectively. The result for a case of binary vibrations of deflection-aileron type will be discussed. Although the details as to the moments of inertia, elastic resistance, damping, etc., are omitted, the discriminant Δ in $(\text{dyne.cm.sec.})^6$ for any wind velocity V assumes, at all events, the type indicated in Fig. 2. This shows that the vibration is unstable through the range of wind velocities between 5 m./s. and 8.5 m./s. The observed vibration amplitudes of the main wing at different wind velocities are shown in Fig. 3. Since the time marker indicated 1/25 of a second on the records, it was an easy matter to find the accurate vibration frequencies of the wing system at the same time. The rotoscope also enabled the confirmation of the vibration frequencies not only at the wind velocity at which the vibration amplitudes were photographed, but also for those at intermediate velocities. The thick full line in Fig. 4 gives the observed vibration frequencies N at flutter condition of the wing, namely, the condition under which the wing vibrates with large amplitudes, whereas the broken line gives the vibration frequencies outside the range of flutter condition. The amplitudes of the main wing in flutter condition shown in Fig. 3 were reexamined and the result was plotted in Fig. 5, the upper as well as the lower criticals of the flutter condition being shown by the short vertical strips at the ends of the curve. It will be seen from this figure that the amplitude of vibration assumes its maximum value near the mathematical upper critical of the flutter and dies away towards both upper and lower wind velocities, the diminution of the amplitude towards the lower wind velocity being rather more gradual than towards the upper wind velocity. This suggests that a condition of selective resonance participates in the phenomena of flutter near the upper critical of the range of free flutter.

Although in the present case the vibrational frequencies of flutter do not change markedly with difference in wind velocity, the same frequencies in certain other cases, for example, in the case of torsion-aileron flutter of a wing with its torsional axis very near its leading edge, the vibrational frequency increases enormously with increase in wind velocity.

The cinematographic study shows that, in flutter condition, the lag in phase of the aileron from that of the main wing is about 90° for the lower range of flutter, while the lag assumes a somewhat smaller value for the upper range of the same flutter.

COMPARISON OF THE EXPERIMENTAL RESULT WITH THE PREDICTION FROM CALCULATION

From Eqs. (4) and other equations it will be seen that, as a rule, there are two frequencies of vibrations at any wind velocity, whether the vibration is in flutter

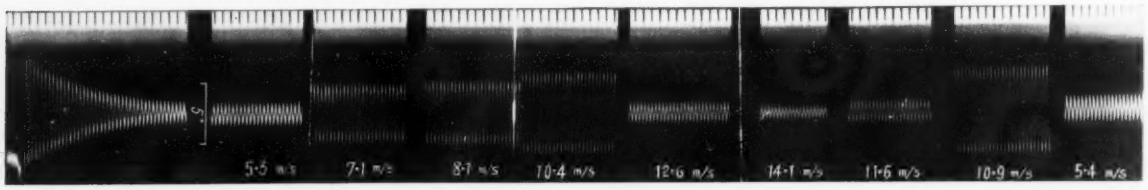

FIG. 3.

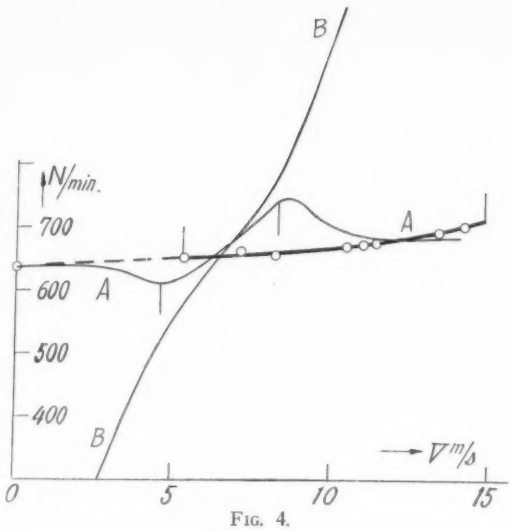

FIG. 4.

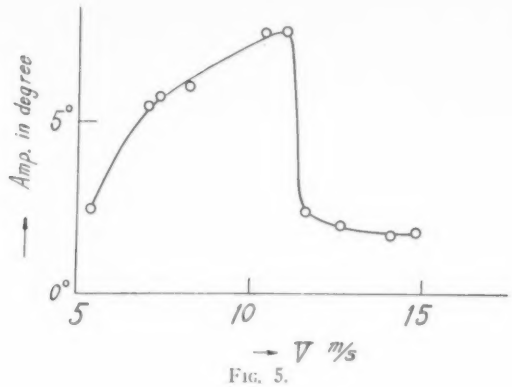

FIG. 5.

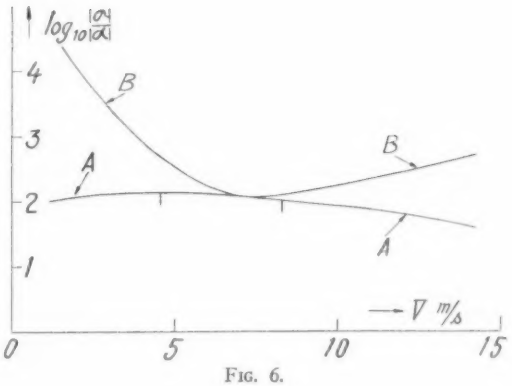

FIG. 6.

condition or not, so that there are two frequency curves. The calculated result is shown by the two thin curves, A and B, in Fig. 4. While instability of vibration is indicated by a certain part of one curve, A, the corresponding part of another curve, B, has no place in the problem of the flutter. The vertical strips show the extreme ends of the part in A that represents the instability of the vibration just mentioned. Notwithstanding that the lower critical wind velocity determined mathematically fairly agrees with that obtained experimentally, for the upper critical of the flutter there is still a marked difference between the values derived from the two methods under consideration. However, although the observed vibration amplitude assumes its maximum value in the vicinity of the mathematical upper critical, the same amplitude diminishes sensibly beyond that critical towards the wind velocity that corresponds to the observed upper critical. This appears to confirm the possible existence of such selective resonance as has just been explained. The wind velocity at the lower critical is too low to give rise to sensible turbulence, manifesting therefore no sign of selective resonance at that lower critical. Although separation of the amplitudes that are due to forced flutter from the superposed one is somewhat difficult, the effect of such forced flutter is so marked that the maximum of the amplitudes of the forced flutter is of the same order as that of free flutter as might be seen from Fig. 5.

It is odd that two frequency curves should approach close to each other in the mathematical flutter range of wind velocities. Outside the same range, on the other hand, the two curves are quite separated from each other. When a part of curve A is extended outside the range of flutter, it tends to assume the frequency values of the main wing with fixed aileron, whereas when a part of curve B is extended outside the same range, it tends ultimately to assume the values of the vibration frequency of the aileron alone at the corresponding wind velocity. It is therefore probable that such extended parts of curves A and B represent coupled oscillation with the vibration energy accumulated in the main wing and the same with large aileron amplitudes, respectively.

The formulae for the relative amplitudes of vibrations in the main wing and the aileron have already been shown in Eqs. (8), (9) and (10), namely, $|\sigma|/|\alpha| = \sqrt{Q^2 + R^2}/P$. The calculation is shown in Fig. 6, the short vertical strips affixed to curve A representing the criticals of the flutter. It will be seen from this figure that, although the angular amplitudes of the aileron are much larger than those of the main wing, which is inherent from the nature of the problem, there is no doubt that the relative amplitude of the main wing to that of the aileron for the vibration A is enormous compared with that for vibration B, being a thousand times, or more.

As to the phase difference for vibrations of type A, the value of $\tan^{-1}R/Q$ calculated from Eqs. (10) is likely to coincide with that observed by the cinematograph for any wind velocity.

The relative amplitudes in the aileron and in the main wing in forced vibration may be found from Eqs. (13) and (14). The calculated values in the special case wherein the frequency of disturbance synchronizes with

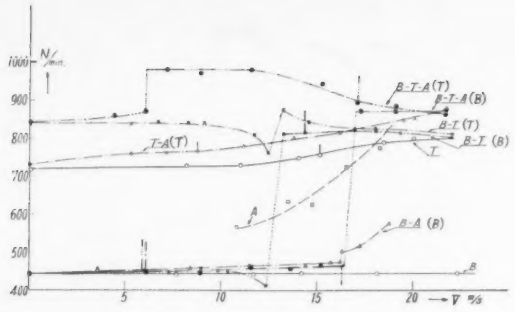

FIG. 7.

any one of those shown by frequency curves *A* and *B* in Fig. 4 are quite the same as those in Fig. 6—an agreement, however, that is obvious from dynamical theory.

Although in the present example, the case of deflection-aileron flutter alone is discussed, it is also possible for similar conditions to exist in other kinds of binary flutter, the most important modification expected in such kinds of flutter being the change of vibrational frequencies for different wind velocities.

AN EXAMPLE OF AN EXPERIMENTAL RESULT IN CONNECTION WITH A TERNARY FLUTTER

The model experimented with for ascertaining the nature of ternary flutter was the U.S.A.35A. The total mass, span, chord, and aileron chord was 615 gm., 34.4 cm., 10.0 cm., 2.5 cm. respectively, details regarding moments of inertia, elastic resistance, damping, etc., being again omitted. The vibrational frequencies observed both within and without the range of flutter for seven different conditions of the wing were: a condition of ternary vibration of deflection-torsion-aileron type; three conditions of binary vibrations, namely, deflection-torsion, deflection-aileron, and torsion-aileron; and three conditions of unitary vibrations, namely, deflection, torsion, and aileron; B-T-A, B-T, B-A, T-A, B, T, A indicating the respective conditions under consideration. The result of these observations is shown in Fig. 7, in which B-T-A(B), B-T(B), B-A(B), B are frequency curves of the respective conditions obtained from the records on the drum for deflection displacement, whereas B-T-A(T), B-T(T), T-A(T), T, A are those of the corresponding conditions obtained from the records on the drum for torsion displacement. The lower and the upper (if existent) criticals of the flutter condition of every case are shown by vertical strips affixed to the curve of that case.

The ternary vibrations B-T-A begin to assume flutter condition at a wind velocity of 6m./s., its type being mainly deflectional, whereas the type of flutter changes from deflectional to torsional at a wind velocity of nearly 16m./s. At these particular wind velocities there are discontinuities in the frequency curves corresponding to types B-T-A(T) and B-T-A(B), respectively. The binary vibrations B-T, B-A, T-A enter the flutter state at wind velocities of about 14m./s., 6m./s., and 9m./s. respectively. In vibration B-T there are again discontinuities in both frequency curves B-T(B) and B-T(T) just below the flutter range. It is possible to interpret these discontinuities and also to ascertain the nature of the flutter conditions obtained from the present experiment by comparing the result with the prediction calculation, but, owing to complexities in treatment, the matter will not be gone into in the present paper.

Institute Notes

Meetings

December 4, 1936. Dinner given by the Institute of the Aeronautical Sciences in honor of Dr. George W. Lewis, at which the Daniel Guggenheim Medal will be presented to him. Hotel Biltmore, New York. During the day a joint technical aeronautical meeting of the A.S.M.E. and the I.Ae.S. will be held.

December 9, 1936. Technical meeting, Air Races, Miami, Florida.

December 28, 1936-January 1, 1937. American Association for the Advancement of Science Annual Meeting and Science Exhibition, Atlantic City.

December 29, 1936, 2 p.m. Aeronautic Meeting of the I.Ae.S., Atlantic City.

January 27-29, 1937. Annual Meeting, I.Ae.S., Columbia University, New York.

Fifth International Congress for Applied Mechanics (1938)

The American Committee, to whom has been delegated responsibility for organizing the Fifth International Congress for Applied Mechanics by the International Committee at its meeting at Cambridge University, England, in July, 1934, announces that the Fifth Congress will meet in Cambridge, Massachusetts, U.S.A., September 12-16, 1938, at Harvard University and the Massachusetts Institute of Technology. As in the past, this Congress is to be a meeting of persons working in the field of Applied Mechanics before whom reports of recent work may be presented for discussion.

The program will cover three main divisions of Applied Mechanics as follows:

I. Structures, Elasticity, Plasticity, Fatigue, Strength Theory, Crystal Structure.

II. Hydro and Aerodynamics, Gasdynamics, Hydraulics, Meteorology, Water Waves, Heat Transfer.

III. Dynamics of Solids, Vibration and Sound, Friction and Lubrication, Wear and Seizure.

Following the meeting at Cambridge, Mass., it is expected that arrangements will be made to visit Washington (National Bureau of Standards), and Langley Field (National Advisory Committee for Aeronautics).

Dormitory and boarding facilities will be made available by Harvard University.

Inquiries should be addressed to the,
Fifth International Congress for Applied Mechanics,
Massachusetts Institute of Technology,
Cambridge, Mass.
U.S.A.

Th. von Kármán
J. C. Hunsaker
Secretaries

The Contribution of Physics to Aviation

A program on *"The Contribution of Physics to Aviation"* was presented under the auspices of the American Institute of Physics and the Institute of the Aeronautical Sciences, Friday, October 30th, from 4:00 to 4:30 p.m., over a coast-to-coast Columbia Broadcasting System network through station WABC, during the occasion of the American Institute of Physics Anniversary Meeting in New York City. Dr. Clark B. Millikan, Associate Professor of Aeronautics at the California Institute of Technology, and a Fellow of the Institute of the Aeronautical Sciences, read a paper on *"The Physicist Gets Air Minded"* during the morning session of this meeting.

During the afternoon broadcast, Dr. Stephen J. Zand and Mr. Preston R. Bassett of the Sperry Gyroscope Company, Fellows of the Institute of the Aeronautical Sciences, cooperated with Dr. Millikan. Dr. Millikan led the program from the studio, while Dr. Zand and Mr. Bassett, in an Eastern Air Lines plane flying over New York, dramatized the take-off and flight of a scheduled transport plane from Newark Airport.

The flight served to demonstrate the vitally important functions of flight instruments and navigation instruments, and illustrated some of the important phases of modern aeronautics in which physics plays a part. During the flight "listeners-in" had the opportunity of hearing, via re-broadcast short-wave, actual reception of radio beacon signals, weather reports, etc. Readings and methods of operation of some of the important instruments on the airplane instrument board were given, actual flight conditions were explained, and the full routine of flight, from take-off, raising landing gear, etc., was broadcast.

Student Branches

University of Detroit. This Student Branch met on the evening of September 30, with a very large attendance. Three speakers were included on an interesting program. They were Roy Leavell, an official racing timer, William Sherman, official N.A.A. Michigan representative and Arthur Schultz, President of the Detroit Glider Council.

Mr. Leavell's experience had taken him into practically every major field of racing. He displayed an automatic recording device for timing up to one-hundredth of a second.

Mr. Sherman's talk concerned the history and future of Gliding and Soaring. He is one of the pioneer gliding pilots of the state of Michigan.

Mr. Schultz gave an official report of the First Midwest Gliding and Soaring Meet that was held at Sleeping Bear on the sand dunes of Lake Michigan.

Following the evening program new officers were elected.

University of Michigan. The first meeting of this Student Branch was held on Thursday, October 15. A record attendance of eighty-seven were present. Chairman Willis Hawkins called the meeting to order.

B. L. Springer, Honorary Chairman, gave a brief talk explaining the aims of the Student Branch, the advantages of membership, the status of the student after graduation, and the fees for membership.

Faculty members were introduced, those present being Professor M. J. Thompson and Mr. R. L. Thoren. Professor F. W. Pawlowski's illness prevented his attendance.

The speaker of the evening, Wilbur Nelson, recently affiliated with the engineering department of the Lockheed Aircraft Corporation, was introduced by Mr. Hawkins. Mr. Nelson, who pioneered in the development of the present University of Michigan Student Aeronautical Organization, talked on the engineering behind modern transport airplanes. The meeting was adjourned at 9:30 p. m.

On Saturday, October 17, forty members of this Branch attended the Mitchell Trophy Air Races held at Selfridge Field.

New York University. A meeting of this Student Branch of the Institute was held October 30 at the University. New officers for the year were elected. They are Richard L. LeTourneau, Chairman; Howard Wittner, Vice-Chairman; and William Hammer, Secretary-Treasurer.

A schedule for meetings was decided on, and the questions of obtaining speakers, trips to plants and factories connected with the aircraft industries, etc., were discussed.

Carnegie Institute of Technology. A meeting of this Student Branch of the Institute was held October 13, 1936. Philip Bright, one of the Student Members, gave a general description of the Taylor Aircraft Company at Bradford, Pa., and related some of the interesting experiences he had during his stay there last summer. Victor Saudek talked on the meet at Elmira and also gave a brief description of Du Pont's glider flight.

George B. Thorp, Honorary Chairman, suggested that a seminar on meteorology be held and preliminary arrangements were made to show films on "Safety on the Federal Airways", sent by the Department of Commerce.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have requirements listed without charge.

Wanted

Flight test engineer to handle the following type of work and who, at the present time, is either desirous of making a change in employment or is actually unemployed.

Flight Test Observation

Accompanying the test pilot on flight tests. The recording of results and the preparation of test reports. Prediction of complete performance characteristics at various altitudes with various types of propellers, both with fixed pitch, controllable pitch and constant speed.

Department of Commerce Type Tests

The preparation of load and ballast arrangements. The computation of takeoff and climb characteristics. The compilation of the Type inspection Report, Department of Commerce Form 46 (revised). The preparation of Weight and Balance Reports.

Engine Temperature Tests

Accompanying the test pilot on climb and other tests for the purpose of determining the maximum temperatures attained by cylinders, oil systems. The determination of exhaust system back pressure, engine baffle differential pressures. The compilation of reports on the foregoing. The computation of horsepower output from considerations of manifold depression and r.p.m.

Miscellaneous Flight Testing

Accompanying the test pilot on stability tests. Measurement of oscillations. Determination of stability coefficients. Observation of flutter.

The holder of this position should preferably be a licensed pilot and have had some engine experience, although this is not absolutely essential. He should, however, have had considerable experience in flying and flight testing. He should have sufficient technical education and training to undertake the mathematics involved in this class of work. He should be capable of accurate observation and intelligent interpretation of what he sees.

The position is for immediate acceptance and the terms of remuneration will be discussed with the applicant. Write Box 49, Institute of the Aeronautical Sciences.

Letter to the Editor

October 27, 1936

To the Editor
JOURNAL OF THE AERONAUTICAL SCIENCES
Rockefeller Center, N. Y.

Dear Sir:

In the article on "Spinning and Tail Buffeting Tendencies and Means by Which They Can Be Detected and Suppressed on a Complete Scale Model in a Wind Channel" by William E. Hunt in the October issue of the Journal, I do not believe that the conclusions drawn by the author as to the probable spinning tendency of the full-scale airplane are justified by the experiments reported.

In tests 1, 2 and 3 the model was free to rotate about an axis normal to the wind direction while it was fixed at various angles of attack. The fact that the model did not oscillate about the axis and its neutral position remained parallel to the wind direction merely indicated that the yawing moments due to yawing velocity and angle of yaw were of the correct sign.

However, the tendency of the airplane to spin is determined by a combination of six moment components and it is impossible to predict from the knowledge of the direction of only two of these components whether or not the airplane will have a tendency to spin. Moreover, no wind tunnel test is required to show that the damping of yaw about an axis normal to the wind direction will have the correct sign. An elementary examination of the yawing moment of the drag of the wings due to yawing velocity shows that this moment will always oppose the motion. Furthermore, in motion about this normal wind axis there is no possibility of obtaining a moment component due to yawing velocity that will reverse this sign.

OTTO C. KOPPEN

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

The Aerodynamics of High Speeds. W. Margoulis. The aerodynamics of high-speed projectiles, wings, and propellors are discussed, the author's seven years of work on high-speed wind tunnels is reviewed, and a theoretical solution is given for the transmission of heat and friction in compressible fluids animated at high speeds. La Technique Aéronautique No. 140, pages 107–157. 28 illus.

The Aerodynamics of the Sky Louse. W. Tye. Results of tests made at the request of the French Air Ministry on a scale model of a Sky Louse, or Pou-du-Ciel, in a wind tunnel operated by the French Service Technique. Behavior at high and low incidences and aerodynamic efficiency are discussed. Abstracted from L'Aéronautique, March 1936. A letter included gives calculations made in some Canadian tests of the Sky Louse. Aeroplane, Aeronautical Engineering Supplement. September 16, 1936, pages 358–359.

Technical Institutions in Germany. Organization and objectives of the "Lilienthal-Gesellschaft fuer Luftfahrtforschung" and the "Deutsche Akademie der Luftfahrtforschung," new German aeronautical research institutes, are explained. Aeroplane, Aeronautical Engineering Supplement. September 16, 1936, page 357.

The Construction and Utilization of an Industrial Wind Tunnel. R. Boname. Development of a wind tunnel for Lioré et Olivier, the measuring instruments used, and the research carried out in the tunnel are described. Means employed for checking the accuracy of the tests, introduction of propeller slipstream by means of small motorized models, a more exact method of representing the drag of engine groups and radiators, a study of the efficiency of control surfaces, and means for representing the flow of air are discussed. L'Aeronautique, August 1936, pages 165–173. 14 illus.

The National Physical Laboratory. Research in the Aerodynamics Department. Aerodynamic effects at high Reynolds numbers, surface roughness and drag of airplanes, model and full-scale comparison, thick wing sections, landing of airplanes and wing flaps are covered. Continuation. Engineering, September 25, 1936, pages 326-329. 8 illus.

Aircraft Design

Bomber Aircraft. The required bomb load, load mobility, range, armament, and performance of bombers are touched upon in a general discussion amplifying an article which appeared in the previous issue under the same title. Royal Air Force Quarterly, July 1936, pages 307-312.

Calculation of the Terminal Velocity of an Airplane in a Vertical Dive. W. H. Miller and P. M. Magruder. Method of calculating the terminal velocity of an airplane either with a fixed or variable-pitch propeller. Results obtained by this method, which has been in use with considerable success since 1932, are said to agree closely with the actual diving velocity of the airplane, and the method is considered suitable for design purposes. Aero Digest, October, 1936, pages 48, 50. 4 illus. 9 tables. 4 equations.

Tomorrow's Clippers. I. I. Sikorsky. Present trends in the development of transoceanic equipment will shortly result in the establishment of a scheduled air service to Europe by luxurious air transports operating on a 20-hour flying-time basis. Problems of transoceanic flying equipment are taken up and tables are included which give comparative data based on a range of 1,000 miles, comparative efficiency, and comparative range for the S-40 and S-42B flying boats. A few particular factors that influence the relation between size and efficiency, power for operating the controls, and power plants are discussed. A table is also given showing the resustance and power required to overcome the parasite drag of different flying boat hulls per 1,000 cu. ft. of pay space at 160 m.p.h. at sea level. Aviation, October, 1936, pages 15-17, 49. 3 illus. 4 tables.

The Feasibility of 125-Ton Aerial Streamliners. Glenn L. Martin. "Based on studies made to date, it would be perfectly feasible to proceed with the detailed engineering design of a 250,000-lb. airplane having a useful load equal to more than 50 per cent of its gross weight. This airplane in transatlantic service could carry a payload of about 56,000 lb., consisting of about 150 passengers, 7,500 lb. of baggage and more than 24,000 lb. of cargo and mail." Very brief suggestions for such a plane. U. S. Air Services, September, 1936, page 13.

Flight on Rotating Wings. W. L. LePage. Various types of rotary-wing aircraft are referred to in a historical survey of the development of this type of aircraft and the theoretical and technical aspects of flight on rotating wings are discussed. Principles of the autogiro and possibilities of the helicopter are pointed out, and mathematical relationships involved in hovering flight are analyzed. Failure to balance rotor torque and the excessive disk loading are explained as two of the causes of helicopter failure. The Army Pitcairn and Kellett autogiros are illustrated. Journal Franklin Institute. September, 1936, pages 255-288. 21 illus.

The Fowler Wing Flap. H. D. Fowler. The designer's description of the theory and uses of the Fowler wing flap. Factors contributing towards increasing lift, partial span and lateral control, design loads on the main wing and Fowler flap, two methods of control, partially extended characteristics, and effect of the Fowler flap on longitudinal stability and downwash, landing distances and rates of descent, take-off of landplane and seaplane, climb and ceiling, and cruising range are discussed. Aircraft Engineering. September, 1936, pages 247-249. 4 illus. 4 tables. Aero Digest. September, 1936, pages 46, 48, 50. 4 illus. 4 tables.

Tapered and Twisted Aerofoils. J. H. Crowe. It has yet to be demonstrated that the premature burbling at the wing tips of a highly-tapered wing seriously impairs the roling moment characteristics of the wing above the stall. If it does, the most obvious remedies are either to twist the wing or to fit wing-tip slots. When flaps are fitted, it is suggested that these alone may exert a powerful stabilizing influence. There are two main drawbacks to twisting a wing: extra induced drag, and increased down load on the loading edge of the wing in a terminal velocity dive. The four methods developed for finding the load grading of a tapered twisted wing below the stall include: the trial and error, Fourier-series, Lotz, and induction-factor methods. Long discussion of the characteristics of this type of wing. Aircraft Engineering. September, 1936, pages 250-255. 9 illus.

Stress Analysis and Structures

Elastically Encastred Struts. N. J. Hoff. Deflections, stress, and critical load of an elastically encastored strut may be put equal to those of a pin-jointed strut of equal size and material but of reduced length. This equivalent length λl has been computed and graphically represented in function of the relative stiffness factor. Formulas are developed for computing the critical load of struts, stocky struts, initially-curved struts, and the failure of framework members under end compression. Journal Royal Aeronautical Society, September 1936, pages 663-680. 15 illus. 44 equations.

Buckling of Rods of Variable Section. F. Orain. Formulas are developed for the variations of the section for rods in compression. An example is given for determining the load which can be carried before rupture by a rod perfectly articulated at its ends and consisting of a profiled tube of duralumin reinforced inside by two flanges fastened to the tube and variable in thickness and length. L'Aéronautique, L'Aérotechnique Supplement, August 1936, pages 101-107. 8 illus. 7 equations.

New Light on the Panel Problem. E. J. A. Greenwood, Jr. For calculating unstiffened aluminum-alloy panels, both flat and curved, a method of apparent widths is described which gives agreement with test results for the allowable compression on the panels which is within the limits of variation of the properties of the material. The method is applicable to any aluminum alloy provided that the correct value of the yield point is known. For predicting the allowable load on stiffened panels the method suggested by Newell is considered satisfactory provided the design is good. Aviation, October 1936, pages 33-36. 4 illus. 3 tables.

Stresses in the Rings of Stressed Skin Fuselages Due to Vertical Shears. G. F. Wallace. Particular cases are presented for the stresses due to vertical shears for rings of any shape and the methods are developed from a least work analysis of the structure. Continuation of article which appeared in the Journal of the Royal Aeronautical Society, April. Flight Aircraft Engineer Supplement, October 1, 1936, pages 17-19. 9 illus. 33 equations.

Aircraft

American Versus British Aeroplanes in South Africa. Views of J. Williamson, manager of the Air Taxi Company of Capetown, South Africa, giving his reasons for favoring American airplanes in preference to the British. Aeroplane, September 16, 1936, page 362.

BELGIUM

The S.E.A.-1 Light Bimotor. A. Frachet. The Belgian 6-passenger low-wing monoplane is powered by two Armstrong-Siddeley Genet-Major 165-hp. engines. It has a top speed of 280 km. per hour and a range of 1,850 km. with 380 kg. of fuel. Long description. Les Ailes, September 3, 1936, page 3. 3 illus.

FRANCE

The new Potez 630 military airplane is said to be the fastest in the world. Its prototype, in tests at Villacoublay, reached a speed of 500 km. per hour when powered with two groups of Hispano-Suiza 79.00 engines. Brief reference with a very poor photograph. Les Ailes, September 3, 1936, page 9. 1 illus.

Improvement in the Standard of the Air Force. New types of French heavy bombers, bomber-fighter-reconnaissance, two-seater reconnaissance, two-seater fighter, and single-seater fighter airplanes. Cruising speed, range and armament of these airplanes are given as well as the calculated top speeds of the Morane 405, Loire 250, and Nieuport 160 single-seater fighters which are undergoing tests for the French air force. Royal Air Force Quarterly, July 1936, pages 397-398.

The Leo, H-47 Transatlantic Seaplane. A. Frachet. The Leo H-47 is powered by four Hispano-Suiza 860 hp. engines arranged in tandem and has a top speed of 360 km. per hour at 1500 meters. Long description. Les Ailes, September 10, 1936, page 3. 3 illus.

The Morane MS 405 Pursuit. The pursuit plane is armed with a 20 "Canon" and two machine guns, is powered by a Hispano-Suiza 12YGr 860-hp. engine, has a top speed of 480 km. per hour at 4,000 m. and climbs to 5,000 m. in 5 minutes. Photograph only. L'Aérophile, August 1936, page 172. 1 illus.

Reviving the Tandem. The Mauboussin "Hemiptere" has front and rear wings of different airfoil sections. The rear wing is mounted on top of the fuselage while the front wing is attached to the bottom of the fuselage. The area of the rear wing is 60 per cent of the front-wing area. Some loss of efficiency introduced by the tandem arrangement has been recovered by placing the fins and rudders at the ends

of the rear wing, reducing "end losses," an arrangement which has recently been used with success in French and British bombers. Brief description with polar diagrams. Flight, September 17, 1936, pages 292d-293. 4 illus.

The Dewoitine D-338 Transport. A. Frachet. The monoplane described is equipped with three Hispano-Suiza 9-Vd. 575-hp. engines, has a top speed of 301 km. per hour and a range of 2,000 km. and carries a pay load of 2,500 kg. Long description of transport being constructed in series for Air France. Les Ailes, August 27, 1936, page 3. 3 illus.

A French Fighter for the R.A.F. The Dewoitine D.510 single-seater fighter bought by the British Air Ministry for research is a low-wing monoplane with an Hispano-Suiza moteur-canon which has a 20-mm. quick firing gun firing a shell weighing rather more than ¾ lb. Brief reference. Aeroplane, September 2, 1936, page 295.

Tests of Autogiros. M. S. Ducout. A few details of the Liore-Olivier autogiro and test results with only a brief reference to the Cierva C. 30. L'Aerophile, August 1936, pages 179-180. 3 illus.

Tests of the Lacroix-De Nazaris Tandem-Wing Airplane. Brief details of a light tandem-wing airplane. Les Ailes, September 10, 1936, page 12.

French Military Aircraft. P. M. Magruder. Armament, performance, and other details of French heavy night bombers, light observation or reconnaissance planes, flying boats, and naval seaplanes. The general trend in France is towards multi-engine military and commercial planes. All heavy fighters of the multi-purpose class are bi-motored, capable of flying one one engine, and can perform a variety of duties. It is highly probable that within a few years no fighter or bomber will be without at least one "motour-canon," but its value at present is limited by the weight of the shell. Concluded. Aero Digest, September 1936, pages 28-31. 12 illus.

Lé O-H47. The Lioré et Olivier H47 transatlantic seaplane is equipped with four Hispano-Suiza 860-hp. ethyl-glycol-cooled engines and has a top speed of 360 km. per hour. Photographs only. Les Ailes, August 20, 1936, page 1. 4 illus.

Specifications of Aeronautical Equipment. The Dewoitine D.333 long-distance transport, D.338 24-passenger transport, and D.371 pursuit monoplane, and the Gnôme Rhône 7 Kfs, 9 Kers, 9 Kfr, 14 Kfs, 14 Kirs, 14 Kjrs, 14 Kfrs, and 14 Klrs engines. Characteristics and performance of each. La Technique Aéronautique No. 140, pages 86–105. 34 illus.

GERMANY

The DO 22 Seaplane. The three-place long range reconnaissance, bomber or torpedo monoplane may be powered by a Hispano-Suiza V engine or a Gnome Rhone K 14 700–900-hp. engine. When powered with the latter the plane has a top speed of 325 km. per hour. Short description. Rivista Aeronautica, August 1936, pages 197–199. 3 illus.

The Dornier Do-18 Flying Boat. While this boat is designed primarily for ocean mail carrying, it is said to be adaptable for military use, particularly as a long-range reconnaissance craft or bomber. The flying boat is an all-metal high-wing braced monoplane powered by two Junkers Jumo 205-C V-type Diesel engines arranged in tandem. Based on a cruising speed of 130 m.p.h. the flight range is 2,670 miles and the fuel consumption 2.29 lb. per mile. In the experimental service between Berlin and New York which is planned by Luft Hansa, Do-18 flying boats will operate from Berlin to a catapult ship near the Azores. Long description. Aero Digest, October 1936, pages 58, 60. 3 illus. Characteristics and performance. L'Aérophile, August 1936, page 173. 3 illus. A few details of the Dornier Do 18 and Do 20. L'Aéronautique, August 1936, pages 174–175. 5 illus.

The Junkers Ju 86 Bimotored High-Speed Transport. Construction details. L'Aéronautique, August 1936, pages 174–175. 5 illus.

The Focke-Wulf F.W.-58 "Weiher" military airplane, designed for training in piloting two-motored airplane, is powered with two Argus inverted 240-hp. engines. Photographs of the plane and cockpit. Les Ailes, August 20, 1936, page 9. 2 illus.

GREAT BRITAIN

Empire-Boat Progress. Views of the Short Canopus flying boat and notes on this plane which is being completed in the Short Brothers plant. Flight, September 10, 1936, pages 264–265, 262. 5 illus.

Getting Their Own Back. The Bristol Aeroplane Company has been flying a new low-wing monoplane which the Air Ministry has ordered for research in flying at great heights. The Bristol Company are building Pegasus motors with two-speed superchargers and a special suit has been devised for the high-altitude pilot. Brief reference. Aeroplane, September 2, 1936, page 292.

Keep an Eye on the British. Innovations in British military aircraft and four experiments in the British commercial aircraft field. Very brief editorial. U. S. Air Services, September 1936, page 10.

A Pippin. The prototype Bristol Blenheim medium bomber is powered with a pair of the latest Mercury engines which give 840 hp. at 14,000 ft. The airplane is said to be the fastest twin-engined bomber in the world and faster than the fastest fighter. Photographs only. Flight, September 10, 1936, page 272d. 3 illus. Aeroplane, September 16, 1936, page 344. 2 illus.

The British High Altitude Record. The Bristol 138 airplane described recently reached a record height of 49,967 ft. It was designed for the British Air Ministry for the study of special problems involved in the operation of aircraft and in the functioning of aircraft and equipment at extreme altitudes. The Bristol 138 is a low-wing monoplane fitted with a Bristol Pegasus specially supercharged engine. Design considerations, details of the structure and engine, special problems in the design of the ccokpit and controls, performance of the airplane, special high-altitude pressure suit for the pilot, special instruments for record determination, and fuel and oil requirements are described. Engineer, October 2, 1936, pages 342–343. 2 illus. Constructional and calculated figures, description of the airplane and equipment, and a drawing of the cockpit showing the instrument board and controls. Flight, October 1, 1936, pages 339–340, 348. 13 illus.

The Four Winds. The Bristol 142 was designed to cruise at 250 m.p.h. on the power of two Mercury VI engines of 605 hp. each. Brief reference to stalling speed and weights. Flight, October 1, 1936, page 335.

A New Light Pusher. The Dart Pup single-seater high-wing pusher monoplane in which the wings have been swept back considerably to give inherent stability. The plane is powered with a 25–27 hp. Ava four-cylinder two-stroke engine. Flight performance discussed and specifications given. Aeroplane, Aeronautical Engineering Supplement, September 30, 1936, page 417. 1 illus.

Portsmouth Points Noted by Artist and Camera. Technical details of the airplanes entered in the Johannesburg Race. Flight, October 1, 1936, pages 342–344. 10 illus.

Primarily for Training. The C.L.W. Curlew T.1 training monoplane is powered with a Pobjoy Niagara III engine driving a propeller of unusually fine pitch. A top speed of 125 m.p.h. is obtained. Brief details of construction. Flight, September 17, 1936, page 296. 3 illus.

Towards an Ideal. A dihedral on the tailplane dispensing with the rudder and spoilers placed well forward on the airfoil are features of the Sykes pusher monoplane which are discussed with some criticisms. Flight, September 24, 1936, page 328. 2 illus.

ITALY

Italian Military Aircraft. P. M. Magruder. Armament, performance, structure, and power plant of Italian fighters, reconnaissance and observation land planes, seaplane fighters, and light observation seaplanes. Italian air strategy and policy in the Mediterranean area as well as the new program of renovation and expansion of the military and naval air forces are discussed in the introduction. At the end of 1936 it is said that Italy will have approximately 5,000 airplanes about half of which will be up-to-date and first-line combat aircraft. To be continued. Aero Digest, October 1936, pages 38–40, 102. 11 illus.

A New Form of Control. New form of lateral control employed on the Jona 6 airplane bought by the Italian government. The wing is so hinged that it can tilt or be tilted sideways, while its incidence relative to the rest of the airplane remains the same. Should the wing be displaced downwards or upwards on either side by the action of the air, the correct aileron action to correct the tilt is automatically applied. The plane has a top speed of 124 m.p.h. Brief. Aeroplane, September 30, 1936, page 420. 4 illus.

Savoia S-79B. The new Savoia-Marchetti bomber which is powered by the two Gnome-Rhone K-14 engines is derived directly from the S-79 trimotor which won six world speed records in September 1935. Photographs only. Les Ailes, September 3, 1936, page 1. 4 illus.

JAPAN

Nakajima AN1 and Navy 90 Single-Seater Pursuits. The Japanese AN1 low-wing pursuit monoplane is powered with a Nakajima 550-hp. radial engine, has a top speed of 450 km. per hour, and climbs to 3,000 m. in 3.5 minutes. The Navy 90 pursuit biplane is powered by a Kotobuki 450-hp. radial engine, has a top speed of 310 km. per hour, and climbs to 3,000 m. in 4.10 minutes. Very brief descriptions. Rivista Aeronautica, August 1936, pages 202–203. 2 illus.

U. S. A.

1936 Race Planes, Race People. C. F. McReynolds. An almost complete sweep of the racing field by aircraft powered with engines of the in-line type, with one exception, and the complete dominance of the "clean" airplane are considered as the two outstanding design features of the airplanes flown in the 1936 National Air Races. Design trends and details of those airplanes of special interest are discussed and tables are given showing increase in speeds for the major race championships, and year-by-year performance for the period 1932–1936. Aviation, October 1936, pages 18–24. 22 illus. 2 tables.

Design at the National Air Races. Details of the Caudron-Renault racer, the Folkert's, Crosby, and Elmendorf Specials, and the Rider Racer. Results of the Races are given in a second article. Western Flying, October 1936, pages 8–9, 11–14. 9 illus.

Fleetwings Sea Bird. The shotwelded all stainless-steel 4-passenger amphibian is described in detail. Drawings are given, showing the fuelage construction and schematic layout of the plumbing system which supplies hydraulic power for landing-gear retraction and flap operation. The airplane has a top speed of 150 m.p.h. and is powered with a 285-hp. Jacobs engine. Aviation, October, pages 38–41. 13 illus.

The 1936 Directory of American Military Aircraft. Data on 110 different models of military aircraft which, with one or two exceptions, are actually in the military service either of the United States or some other government. The exceptions are recently completed military models upon which the manufacturers have not yet received government orders. The data apply to 34 fighters, 15 bombers, 28 observers, 10 transports, 15 trainers, and 8 all-purpose airplanes. Western Flying, September 1936, pages 16–38. 65 illus.

C-W Basic Trainer. The Curtiss Model 19-R basic trainer described becomes a two-seat fighter by the installation of a fixed machine gun synchronized with the motor, a flexible machine gun, and bomb racks. Conversion into an attack plane is effected by installing a fixed gun in each landing-gear compartment. Powered with a Wright R975-E2, the airplane has a top speed of 215 m.p.h. as a trainer. Armament, construction, performance, and weights are given. Aviation, September 1936, pages 41, 43. 2 illus. 1 table.

Latest Lockheed. The new Model 12, although smaller, closely resembles the Electra. The airplane is designed to carry six passengers and two pilots, is powered with two 450-hp. Pratt & Whitney Wasp Junior engines, and has a top speed of 214 m.p.h. at sea level. Long description. Aviation, September 1936, pages 33–35. 7 illus.

Improved Performance for NA-16. Up-to-date performance characteristics of the North American Aviation NA-16 general-purpose military airplane. With slight alterations the basic trainer may easily be converted into a fighting ship, for fixed machine-gun fittings have been developed whereby either one or two synchronized guns may be installed, as each is a separate unit. Aviation, September 1936, page 44. 1 illus. 1 table.

The Folkerts Special Racer Flown by Harold Neumann at Los Angeles. F. Knack. The midwing monoplane described is powered by a Menasco Pirate 4-cylinder 185-hp. engine and has a maximum speed of 240 m.p.h. at sea level. Description of construction with particular reference to the retractable cantilever landing gear. Aero Digest, October 1936, pages 64, 102. 4 illus.

Hawks Aircraft. The low-wing cantilever fonoplane designed for Frank Hawks is powered with a Wasp twin-row 1150-hp. engine released for use by special permission of the Army and Navy. Estimated performance indicates a top speed of 375 m.p.h. at sea level. Few details. Western Flying, October 1936, page 26. Preliminary details. Aviation, October 1936, page 45.

The New Douglas Flying Boat. The Douglas DF 32-passenger all-metal flying boat has a 3300-mile maximum cruising range with 12 passengers, or 1500-mile range with full load. Top speed is 185 m.p.h. Brief. Western Flying, October 1936, page 21. 1 illus.

Roadable Autogiro. A few details of the new experimental autogiro capable of being driven on highways, which was recently delivered to the Bureau of Air Commerce. Automotive Industries, October 10, 1936, page 468. 1 illus.

Vought V-143 Pursuit Fighter. Low-wing single-seater fighter on which the Material Division of the U. S. Army Air Corps recently completed tests. Powered with a Pratt-Whitney Wasp Junior 525-hp. engine the plane has a maximum speed of 250 m.p.h. and a range of 1070 miles. Armament, construction, specifications, and performance are given. Aero Digest, October 1936, page 62. 2 illus.

Order Backlogs Grow. Major J. H. Doolittle has ordered a commercial version of the new Seversky pursuit for his personal travel use and as a flying laboratory for experiments with fuels. The ship has a high speed of over 300 m.p.h. and a cruising range of 3000 miles. Brief reference. Aviation, September 1936, page 55.

Spartan Four-Place "Executive" Monoplane. Low-wing cantilever cabin plane which bears a resemblance to the modern airline transport. Description. Aero Digest, September 1936, page 52. 2 illus.

Vought Fighter. The Vought Model V-143 fighter was developed for the Army Air Corps from original designs by Northrop and has been delivered at the Material Division. The airplane has a top speed of 250 m.p.h. at 8000 ft. Details of normal armanent and other equipment and performance. Aviation, September 1936, page 43. 1 illus. U. S. Air Services, September 1936, page 25. 1 illus.

U. S. S. R.

A train of two gliders and an airplane covered a distance of 3000 km. from Turkeston to Moscow in 17 hours 30 minutes, or at an average speed of 171 km. per hour. Brief reference. Les Ailes, August 20, 1936, page 9.

Aircraft Maintenance

The Economy of Regular Overhaul. K. C. Hawkins. Methods of overhauling airplanes and engines. Brief. Western Flying, October 1936, page 23.

Maintenance Procedure at American Airlines' Chicago Base. General discussion of buildings and methods used in the maintenance of the airplanes, engines, propellers and instruments. Aero Digest, September 1936, pages 24–26. 9 illus.

Aircraft Manufacture

The S.A.E.'s Production Forum. Titles and authors of papers presented at the National Aircraft Production meeting at Los Angeles. Western Flying. October 1936. pages 20–21.

Aircraft Performance

To Spin or Not to Spin. O. C. Koppen. A simplified study of the lateral motions of an airplane at high angles of attack. A mathematical analysis is included to substantiate the assumption that the chief difference between high and low angle of attack spiral motion is the direction in which the machine sideslips. An expression is developed for force equilibrium while the angle of bank is changing in a turn without sideslip. A corresponding relation is obtained from the rolling and yawing moment equations. These calculations show that the moment component most likely to cause difficulty at high angles of attack is the yawing moment due to rolling. If it is impractical to avoid a change of sign of this moment at the stall. the author suggests that the undesirable effects caused by it can be eliminated by designing for a large value of the yawing moment due to sideslip. Aviation, September 1936, pages 29–31. 1 illus. 11 equations.

Airships

The Four Winds. The Soviet Dirigible Building Trust has just launched a new airship known as the V-8 which has a volume of 10,000 cu-m. Brief reference. Flight, October 1, 1936, page 335.

Data on Goodyear Airship Fleet. Flights, hours, passengers, and miles for an eleven-year period. U. S. Air Services, September 1936, page 24.

Propellers

Fabrication and Checking of the Blades of Metal Propellers. Sub-lieutenant M. Mercanti. Operations in the production of the blades with particular regard to the thermal treatment, furnaces used, and methods employed for static balancing of the propeller. Rivista Aeronautica, August 1936, pages 171–173.

The Latest Ratier. The pitch of the new Ratier propeller is easily changed in the air by means of a small electric motor and can be varied between wide limits. Should the area motor stop, the blades can be set edge-one to offer minimum resistance. Design and operation of the propeller used by Mrs. Markham in her recent transatlantic flight are briefly described. Aeroplane, September 16, 1936, page 369. 3 illus.

Static Thrust of Airscrews. W. R. Andrews. When allowance is made for the effects of interference and slipstream, remarkable agreement can be obtained between model and full-scale results, the author finds. A method is outlined for calculating the static thrust of propellers. Flight Aircraft, Engineer Supplement, October 1, 1936, pages 13–17. 5 illus. 4 tables. 8 equations.

The Variable-Pitch Propeller. A. Bellomo. The different types of variable-pitch propellers described include the Ratier (three types), Breda-Ratier, Hamilton-Standard (two types), Gnome-Rhone, Eclipse, Levasseur (two types), Savoia-Marchetti, Alfa Romeo-De Caria, Piaggio-D'Ascanio and the Gloster Hele-Shaw Beacham propellers. This description is preceded by a discussion of the advantages and disadvantages of the variable-pitch type of propeller and a classification of these propellers. Rivista Aeronautica, August 1936, pages 141–160. 14 illus.

An Engine-Propeller Chart as a Practical Aid to Calculations. W. F. Eade. Six equations are given in chart form from which the basic data for performance calculations can be obtained. Areo Digest, September 1936, pages 38–39. 2 illus. 6 equations.

Propeller Governor. In the Hamilton-Standard constant-speed propeller control described the pitch is shifted by oil pressure. Counterweights acted on by centrifugal force provide the operating force to move the blades toward high pitch, and the oil pressure works in the opposite direction against the counterweights, setting the pitch to any intermediate position between full low and full high. Pitch is automatically selected by a separate unit called the "Constant-Speed Control" which regulates the oil pressure in the propeller operating cylinder. Construction details. Aviation, September 1936, pages 36–37. 3 illus. Aero Digest, September 1936, pages 36–37, 84. 4 illus. U. S. Air Services, September 1936, pages 19–20. 2 illus.

Rocket Propulsion

Prize Winning Paper on Rocket Design. Development of the rocket motor and details of the latest design. Abstract of paper by A. Africano entitled "Design of a Stratosphere Rocket," which won the Rep-Hirsch Astronautical Competition. Scientific American, October 1936, pages 218, 220. 4 illus.

The Rocket-Propelled Aeroplane. W. Ley. Results obtained by the German Rhön-Rossitten Gesellschaft in tests with rocket-driven airplane models and with two full-sized airplanes, research on the Melot propulsor and thrust augmentors, the Goldau design of explosion chambers with a proposed arrangement in an airplane, Dr. Saenger's design for a rocket airplane for supersonic speeds, R. H. Goddard's patented airplane with rocket propulsion, H. Oberth's theoretical solution for the problems involved in the application of rocket power for aviation, and experiments undertaken at Greenwood Lake are described. Aircraft Engineering, September 1936, pages 257–260. 7 illus.

Records and Races

Digest of Recent Events. Russian 5858-mile non-stop flight, the Gipson speed record for women, the Detre altitude mark of 55,082 ft., the Soviet flight from Moscow to Los Angeles, the women's seaplane records established by Miss Tanner, and a new Hindenburg speed record. Brief review. Aero Digest, September 1936, page 74.

Showing the World. Non-stop flight of the Junkers express air liner Ju 86 covering the 3780 miles betwen Dessau and Bathurst, Africa, in 20½ hours. The Junkers company contend that a performance of this kind can only be done by using Junkers heavy-oil engines which consume only 0.334 lb. per b.hp.-hr. Brief. Aeroplane, September 2, 1936, page 291.

Transatlantic Reciprocity. Adventures of Mrs. Markham and of the Richman-Merrill team in their respective transatlantic flights. Flight, September 10, 1936, pages 267–268. 4 illus.

We Seem to Lead. Of a total of 128 official world's records, American aviators lead with 49. List of American records. U. S. Air Services, September 1936, page 31.

World's Height Record. A new record for airplanes was established when G. Detre flew his Potez 50 (Gnôme-Rhône K.14) to 48,600 ft. Mention is also made of the new Alvis 1400-hp. double-bank 18-cylinder Alcides and the 1000-hp. double-bank, 14-cylinder Pelides engines, the latter being based on the design of the K.14 Gnôme-Rhône engine. Brief reference. Aeroplane, September 2, 1936, page 292.

Areonautics from Day to Day. Events of aeronautical interest which took place during the month of June. L'Aéronautique, August 1936, page 176.

Digest of Recent Events. The Markham and Richman-Merrill transatlantic flights, Louise Thaden's transcontinental mark, the Arnoux speed record, Soviet flight from Los Angeles to Moscow, and the Do-18 transatlantic flight. Brief references with drawing of the Richman-Merrill airplane. Aero Digest, October 1936, page 98. 1 illus.

The Johannesburg Race. Entries, the formula for handicap speed and time, the course from Portsmouth, England, to Johannesburg, pilots and passengers, and competing airplanes and engines are described. Drawing of the B.A. 4 Double Eagle Airspeed Envoy, Percival Vega Gull, Miles Peregrine, Percival Mew Gull, and Miles Hawk Speed-Six show details of interest in these airplanes. The second article describes the preparations and start with a list of starters and handicaps. Aeroplane, September 23 and 30, 1936, pages 374–376, 378–390 and 405–410, 418–419. 64 illus. Handicap formulas and competing airplanes and engines. Flight, September 24 and October 1, 1936, pages 306–308, 310–313 and 332–334. 38 illus.

Over the Route. Flight Lieutenant Tommy Rose. Features and difficulties of the route to Johannesburg as it will appear to competitors in the race. An article entitled "Who's Who In the Race" follows this article. Flight, September 24, 1936, pages 316a–316d and 324–325. 17 and 15 illus.

Results of the Air Races. The 1936 National Air Races and their winners. Aero Digest, October 1936, pages 34, 36. 8 illus. 1 table.

Transatlantic. Survey flight of two German Dornier Do-18 flying boats to New York and launching from the Schwabenland near New York. Brief description and reference to the Beryl Markham, and Merrill and Richman recent transatlantic flights. Aviation, October 1936, pages 51–52. 3 illus.

Engine Design and Research

Combustion Engine Temperatures by the Sodium Line-Reversal Method. M. J. Brevoort. The sodium line-reversal method has been used in some preliminary measurements of flame temperature. Improvements in the method involving a photographic recorder and a means of correcting for the dirtiness of the windows are described. An N.A.C.A. single-cylinder 4-cycle test engine connected to a dynamometer was used in the tests discussed. Review of Scientific Instruments, September 1936, pages 342–346. 5 illus. 1 table.

New Method of Determining Ignition Lag Developed. The method described allows continuous observation of the crank angle at which the fuel injector opens and that at which the fuel begins to ignite, the difference between these two being the ignition lag. The method was developed by A. L. Bird and S. G. Bauer. Brief. Automotive Industries, September 26, 1936, page 422. 2 illus.

New Engines for U. S. Army Air Corps. Tests are being conducted at Wright Field on a number of aircraft engines some of which surpass in power anything now in service. One is a twin-row radial air-cooled 12-cylinder Wright, said to exceed 1200 hp. at sea level, and the other, an Allison 12-cylinder in-line geared engine, is said to have a sea-level output in excess of 1000 hp. Brief reference. Royal Air Force Quarterly, July 1936, page 402.

The Power of Engines and Their Maximum Cross Section. Gorochtenko. Influence of the maximum cross section of the airplane engine on the aerodynamic efficiency of the power developed. Formulas are given and a comparison is made of the Gnôme-Rhône, Hispano-Suiza, Pratt and Whitney, Wright and Renault engines. Long abstract from the Russian review "La Technique de la Flotte Aerienne." L'Aéronatique. L'Aerotechnique Supplement, August 1936, pages 107-111. 2 illus. 1 table. 8 equations.

Engines and Accessories

Cutting Down Noise. The main idea of the Turner silencer is to conduct the exhaust gases straight into an aircooled cylinder. The gases are deflected by a series of aircooled tubes and find their way out through holes in the side of the cylinder diametrically opposite that at which they have come in. Two types are described. Aeroplane, September 9, 1936, page 340. 1 illus.

Oppositely-Running Airscrews. Alvis aircraft engines now in production are manufactured for either right- or left-hand turning. In several other countries, particularly in France, all military machines and the greater number of commercial twin-engined machines are compulsorily fitted with oppositely-turning motors. Brief discussion. Aeroplane, September 9, 1936, page 331.

Sauer Diesel for Light Vehicles. P. M. Heldt. Original form of combustion chamber, design of spray nozzle, and automatic timing gear for an injection pump as well as other features are described. Automotive Industries, September 26, 1936, pages 412–416. 9 illus.

Skinner Filter for Diesel Can Be Cleaned During Engine Operation. The Type F-3 fuel-oil filter described works on the principle of edge filtration as used in the streamline filter for lubricating oils. Automotive Industries, September 20, 1936, page 420. 4 illus.

Supercharger Pressure Regulator. By automatically regulating the throttle, the new unit limits manifold pressure to the allowable boost at take-off and in cruising, regardless of change in engine speed or altitude. Description of device perfected by Eclipse Aviation Corporation with the assistance of Wright Aeronautical Corporation. Aero Digest, September 1936, page 39. 2 illus. Aircraft Engineering, September 1936, page 256. 2 illus.

The Burgess Aero-Engine Silencer. The silencer developed at the Royal Aircraft Establishment comprises a central pipe perforated with a number of comparatively large holes, the holes being surrounded by annular passages in which there are also holes leading to the outer casing. In the set of perforations near the inlet, high-frequency pulsations in the gas entering the silencer are damped out since pressure peaks pass out through the perforations and return to the central pipe during pressure troughs. Test results and brief description. Engineering, September 25, 1936, page 352. 1 illus.

Cartridge Starter. Coffman engine starters developed by the Federal Laboratories have been under test with the Army, Navy and Marine Corps Units and have proved their ability to start engines of the Cyclone or Hornet class satisfactorily at operating temperatures as low as —20° F. Few details. Aviation, October 1936, page 44. 2 illus.

Five Ounces per Horsepower. The Hughes Stressless airplane engine is said to give the extraordinary power-weight ratio of about 5 oz. per hp. A novel design is said to enable relative motion to take place between piston and cylinder, with the result that phenomenal engine speeds may be employed without stress. It is also claimed that the design offers smoothness of torque, approximating that of the turbine and very small frontal area, and that the engine is to a certain degree self supercharging. Very brief reference. Flight, October 1, 1936, page 336.

Flexible Tubing. Avioflex fuel hose for airplanes and motor vehicles is composed of several layers of material which are superimposed on each other perfectly tight, reinforced outside and protected by a strong braiding either of galvanized steel or copper wire. Few details. Aeroplane, September 30, 1936, page 431.

The Four Winds. A number of Handley Page 52 medium bombers ordered by the Air Ministry are likely to have fully supercharged Pegasus XX engines. Brief reference. Flight, September 17, 1936, page 289.

Poyer. The three-cylinder radial aircraft engine described is rated at 46 hp. at 2500 r.p.m. Specifications and construction. Brief. Western Flying, October 1936, page 26. 1 illus.

Sleeve Valves for the Service. Vildebeest IV airplanes will be fitted with Bristol Perseus sleeve-valve engines and the poppet-valve Mercury engine in the Westland army cooperation monoplane will be replaced by a new model of the Perseus. The Perseus VIII develops 810 hp. at 5250 ft. Brief reference. Flight, September 17, 1936, page 285.

An Aviation Engine with a Gas Generator Which Burns Coal Tar Oil. T. Lafitte. The application of special fuels to high-speed Diesel aircraft engines is discussed. The apparatus proposed consists of a gas generator and heaters and is little larger than an ordinary carburetor. It permits the utilization of heavy oil such as coal tar oil or the liquid residue left after extraction of petroleum by the fractional distillation process. Les Ailes, September 3, 1936, pages 5–6. 2 illus.

The Heavy-Oil Engines. Present state of development of the heavy-oil engine for aircraft in regard to weight, endurance, and frontal area. Characteristics of the Baltimore opposed-piston two-cycle, Beardmore flat twin-six, B.M.W. Hornet with the Lanova air chamber, the Botali-Rexovice, Bristol 9-cylinder radial, and Clerget 14-cylinder double radial Diesel engines are given. L'Aérophile, August 1936, pages 185–186. 4 illus.

High-Speed Diesel Engines. H. Ricardo. Experiences of the author's firm and lines of thought followed during the last 16 years in the development of high-speed Diesel engines. The author points out that the Diesel engine of the future will have to be content with a much inferior fuel. His recent work has been directed to the problem of dealing with fuels of the near future and to that end two other forms of combustion chamber have been evolved. Abstract of paper presented before the British Association. Engineer, October 2, 1936, pages 357–358.

DIESEL ENGINES

Tests totalling over 500 hours have been completed on the Z.O.D.-260 Diesel aircraft engine at the Zbrojovka works. It is a 9-cylinder radial two-stroke aircraft engine of 600 lb. rated at 260 hp. Brief reference. Royal Air Force Quarterly, July 1936, page 389.

Fuels and Lubricants

Army Method for Octane Value of Aviation Fuel. Air Corps Specification No. 3566-A, April 15, 1935. Abstract giving essential points in answer to a request for information regarding the method mentioned by Buc and Aldrin. Oil & Gas Journal, October 1, 1936, page 54.

The Characteristics of Fuels for Aviation. P. Prevost. Requisites and characteristics of fuels for aviation. Abstract from Aero No. 1463–1464. Rivista Aeronautica, August 1936, pages 216–217. 1 illus.

Aircraft Instruments

Development and Principles of the Gyropilot. P. R. Bassett. Development of the Sperry Gyropilot since the first invention by Lawrence Sperry in 1914, and its present design and operation are described in detail. Instruments, September 1936, pages 251–254. 13 illus.

Instruments for Navigation. Holmes compass and Smith automatic pilot. Long descriptions. Continuation. L'Aérophile, August 1936, pages 181–185. 7 illus.

With Vanes the Airplanes Fly Alone. Note from L. Constantin on the advantages of his design of an automatic stabilizer over the automatic gyroscopic stabilizers used on American airplanes. Brief. Les Ailes, August 27, 1936, page 3.

Aircraft Radio

Instrument Landing Systems for Aircraft. H. W. Roberts. The Bureau of Air Commerce, the Army-Hegenberger and the United Air Lines systems of instrument landing for aircraft are described. To be continued. Aero Digest, October 1936, pages 43–44, 46. 10 illus.

The Radio Beacons for Landing. P. Larivière. Principles, operation, and installation of the Lorenz and S.I.P.L. (Loth) systems of radio beacons used for landing aircraft. L'Aéronautique, August 1936, pages 155–163. 14 illus.

The Technique of Blind Approach. Recommended methods of using the Lorenz radio system for the landing of aircraft. The maneuvers which are necessary if the receiver is to be used in the correct manner are described and the different indications and their meaning are explained. Flight, September 17, 1936, pages 286–288. 5 illus.

Aircraft Radio Installation. N. J. Clark. Correct installation and testing of the receiver units, power supplies, and antennas are described with special reference to ignition shielding. Western Flying, September 1936, pages 14–15, 38.

R. C. A. Radio Compass. Combination aircraft receiver and homing radio compass is embodied in the new Model A V R-8 described. The compass is helpful also in flying away from a broadcasting station to a point where there is no station by utilizing a reciprocal bearing arrangement. Aviation, September 1936, pages 40–41. 3 illus.

Television in the Sky. A scheme is said to have been worked out in the United States to provide the pilot of an airplane approaching an airport with a picture showing the position of his airplane relative to objects around the airport. Brief reference. Aeroplane, September 9, 1936, page 318.

Tests of a Cathode Ray Direction Finder. C. T. Solt. U. S. Coast Guard tests of a cathode-ray visual radio direction finder, developed by E. Hefele of the Airplane and Marine Direction Finder Corporation. Reliable bearings were consistently obtained through heavy intermittent atmospheric electrical disturbances, as well as through interference from other radio signals on the same frequency as the observed signal. Performance was particularly impressive during night flying and while the so-called "night effect" was frequently noted, directional accuracy of observed bearings apparently was not affected. Equipment used, tests and results, are discussed in detail. Aero Digest, September 1936, pages 18–19, 84. 8 illus.

Meteorology

An Electric Motor for Radiometeorographs. L. F. Curtiss and A. V. Astin. The small light-weight d.c. motor described was designed by the authors in connection with the development of the Olland system of telemeteorography and was used with a radio transmitter carried by a sounding balloon. Review of Scientific Instruments, September 1936, pages 358–359. 2 illus.

Influence of Lake Ponchartrain on Fog Formation at Shushan Airport, New Orleans, La. G. V. Fish. Location of the airport and conditions affecting fog formation there. Monthly Weather Review, June 1936, pages 203–204.

Soaring Flight at Night. Some problems of soaring flight at night as a basis for the study of thermal currents. Abstract from Luftwissen No. 12, 1935. Rivista Aeronautica, August 1936, pages 234–239. 4 illus. 1 table.

Airport Equipment

Asphalt Surfaces for Airports. B. E. Gray. Thickness of the structure and materials and construction of runways are discussed. Aero Digest, October 1936, pages 30–32, 102. 5 illus.

Directory of the Manufacturers of Airport and Airline Equipment. Names, products, and addresses. Aero Digest, October 1936, pages 75–76, 78, 80, 82, 84, 86, 88, 90, 92.

LIGHTING

Controlled Lighting for Landing During Zero-Zero Conditions. J. B. Bartow. A visual contact system of landing under conditions of poor visibility. Lights for guiding the pilot, characteristics and limitations of the color of the lighting, arrangement of lights for runways, and effect of light on the eyes of the pilot are discussed and a light-transmission chart is given showing the amount of candlepower needed for penetration at various distances and transmissions. A system for controlling light projectors according to the transmission of the atmosphere is suggested. Aero Digest, October 1936, pages 25–27. 7 illus.

33-hp. Tractor. Cleveland Model 30 tractor for airport grading work. Few details. Aviation, September 1936, page 47. 1 illus.

Fire Control

Fire Foam Maker. Phomaire Play Pipe developed by Pyrene Manufacturing Company for fighting flammable liquid fires. Few details. Aviation, September 1936, page 46.

Post Prominently! A set of fire-prevention rules for airport operators in regard to smoking and open flames, electrical sparks, static electricity, spontaneous ignition, and flint sparks. Aviation, September 1936, page 28.

Metals

HEAT TREATMENT

Heat-Treatment by Boeing. H. Mansfield. Equipment, materials, and methods employed at the Boeing Aircraft Company with a description of the method of treating wing terminals for the Boeing 299 four-engined bombers and a reference to the method of annealing aluminum-alloy sheet. American Machinist, October 7, 1936, pages 861–863. 3 illus.

STEEL

Why Not Raise the Ante? J. P. Boore. Improved materials and better manufacturing technique for seamless steel tube for aircraft with particular reference to the physical properties and other safety factors. Reference is made to the maximum allowable yield strength under compression as shown in the Army Handbook. The suggestion is made that the entire subject of tubing be reopened and that a new series of empirical tests be made to determine to what extent modern technique may permit an increase in the allowables. Aviation, October 1936, pages 31–32. 2 illus.

WELDING

Spot Welding vs. Riveting. C. W. Steward. Comparative physical properties of spot welded versus riveted aluminum-alloy aircraft construction. Results of comparative tests undertaken by the author at Chance Vought to determine the effects of vibration, corrosion, variation in shear strength from the average value, strength of spot welds in torsion, and amperages for welding materials other than 24 ST Alclad. Continuation. Aviation, October 1936, pages 28–30. 9 illus.

Welding of Aircraft Structures. J. B. Johnson. Applications of oxyacetylene, oxyhydrogen, electric-arc and electric-resistance welding in the production of aircraft structures. U. S. Army and Navy specifications, chemical composition, and tensile properties of ferrous and non-ferrous aviation materials, fatigue characteristics of welded steel tubes, filler metal, fluxes, fusion welds, practices which the designer of fusion welds should avoid, spot welds, heat treatment of welded airplane structures, welding jigs, Army and Navy qualification test for the aircraft welder, and inspection of welded joints are discussed. Contribution for the proposed Welding Handbook of the Society. American Welding Society Journal, September 1936, pages 2–11. 13 illus. 5 tables.

The Jointing of Materials by Welding. R. H. Dobson and R. F. Taylor. Disadvantages of riveting and bolting and the advantages of welded tubular construction under war time conditions are referred to and the oxyacetylene gas welding process outlined. Methods of avoiding cracking and distortion are suggested. The composition and properties of weldable steels, the stainless steels, and aluminum and magnesium alloys used in welded aircraft construction are discussed. Types of joints, repairs, electrical seam welding, spot-welding and arc-welding methods are taken up and comparative test data on riveted and welded spars and on the properties of light alloy spot welds are given. Journal Royal Aeronautical Society, September 1936, pages 647–657 and (discussion) 657–662. 4 tables.

Pressure, Current, Time—On the Spot. C. W. Steward. The three primary variables that affect the quality of the work in aluminum spot welding. Results of a special study made for Chance Vought Aircraft on the time-of-current-flow versus thickness of material, on the electrode pressure, and on weld amperage. Reference is made to Wright Field, Boeing and Aluminum Company of America research results which the author studied as a basis of his investigation. Continuation. Aviation, September 1936, pages 25–27. 8 illus.

Armament

Aerial Fire in the Future. Schvetkoff. Provisions necessary to guarantee the efficiency of fire from an airplane and to reduce to a minimum the physical effort of the gunner. The turret should be maneuvered automatically and for rotation in a horizontal plane it should be rotatable at two different speeds. Abstract from Corriere della Flotta Aerea, No. 2, 1936. Rivista Aeronautica, August 1936, page 182.

Armament of Our Military Airplanes. Supports for the guns mounted on aircraft are described covering gun turrets and cupolas. Reference is made to the turret on the Martin bombers and Short airplanes, and to cupolas on the Bloch 200, Potez 541, Amiot 143, Breguet 460, Boeing 299, Bristol and Paul Overstrand, Farman 421, Leo 208, and Handley-Page airplanes. Continuation. L'Aérophile, August 1936, pages 170–171.

Some Special Solutions for the Motion of the Powder Gas. R. H. Kent. An important error in Pidduck's special solution for the equation of motion of the powder gas in a gun is pointed out and special solutions for the motion of a perfect and an imperfect gas are obtained. Modifications to take account of projectile friction and the burning of the powder are included. Physics, September 1936, pages 319–324. 13 equations.

Air Forces

AUSTRALIA

On Australian Defense. C. G. Grey. Plans for the defense of Australia with special reference to the plans for air-force expansion involving an expenditure of £1,443,652. Three squadrons instead of one will be provided for cooperation with the Field Army, one squadron instead of a flight for naval cooperation, and five squadrons for cooperation with the fixed defenses. Land airplanes will be substituted for flying boats and air-force personnel increased to 2,263. Aeroplane, September 30, 1936, pages 421–423.

CHINA

The Four Winds. Chinese residing in Malaya have given nearly £150,000 to the Chinese Air Force for the purchase of aircraft. Brief reference. Flight, October 1, 1936, page 335.

CZECHOSLOVAKIA

Czech Military Budget for 1936. The Budget for 1936 amounts to over 2 milliard crowns and the vote for military aviation amounts to about 87 million (£725,000). Brief reference. Royal Air Force Quarterly, July 1936, page 389.

FINLAND

Finding Finland. Proposal to use Finland's air force machines and personnel for commercial airline work. Brief reference. Aeroplane, September 2, 1936, page 304.

FRANCE

Foreign Service News. Several French squadrons of aircraft including autogiros took part in the Army exercises in Provence. Expenditure of an extra £56,000,000 has been authorized by the Council of Ministers for this year to be used in strengthening French defenses. Brief reference. Aeroplane, September 16, 1936, page 356.

Pilgrimage to Cazeaux, the Jerusalem of Aerial Gunnery. Commandant A. Langeron. General discussion on the negligence of the French government in the development of armament in the past five years and a few details of the school. Les Ailes, August 20, 1936, page 7.

GERMANY

The Four Winds. A complete squadron of bombers with Junkers heavy-oil engines is in service with the German Air Force. Brief reference. Flight, September 10, 1936, page 266.

GREAT BRITAIN

500 Vacancies Monthly for Aircrafthands. Air Ministry announcement that, owing to the expansion fo the Royal Air Force, an entry of 500 aircrafthands will be required each month until further notice. Brief reference. Flight, September 10, 1936, page 278.

Combined Manoeuvres. The British Combined Manoeuvres which took place on August 26 are criticized. Aeroplane, September 2, 1936, pages 293–294. 3 illus.

The R.A.F. and the Army in Palestine. Appointment of an Army officer to the supreme military control of the British forces in Palestine, in place of the air force officer, is criticized. Brief. Aeroplane, September 16, 1936, page 353. 1 illus.

The Singapore-Sidney Flying-Boat Survey. H. Fysh. The survey described was made in a flying boat of the Royal Air Force over a proposed route along which the fleet of Short flying boats is to assure the British Imperial air communications with Australia. Views are given of the Short Brothers Canopus and Caledonia which are the first of thirty designed especially for the Imperial air routes to Australia, South Africa and ultimately to New Zealand and America. To be continued. Aeroplane, September 16, 1936, pages 347–352. 12 illus.

New Bomber Equipment. Large orders have been placed by the British Air Ministry for two of the long-range bombers, namely the Handley-Page 52 day-and-night fighting bomber and the Vickers twin-motor bomber of geodetic construction. Brief reference. Aeroplane, September 23, 1936, page 391.

A Progressive Engineering Branch for the R.A.F. The good tradesmen are worthy candidates for the post of Engineer Officer. Discussion of previous articles. Royal Air Force Quarterly, July 1936, pages 330–332.

The Singapore-Sydney Flying-Boat Survey. H. Fysh. The journey from Darwin-Mornington Island to Sydney in the R.A.F. flying boat. Concluded. Aeroplane, September 23, 1936, pages 393–396. 7 illus.

HOLLAND

Foreign Service News. The Government of Holland has placed an order for six Dornier trimotored airplanes for the Navy. The order is to be followed by a further order for 36 Dornier machines. Brief reference. Aeroplane, September 30, 1936, page 416.

New Fokker Fighter Aircraft. Fokker Type T.V. twin-engined aircraft, capable of a speed of 223 m.p.h. with a war load, has been adopted by the Dutch Government. The plane carries a crew of four and ten large bombs. Brief reference. Royal Air Force Quarterly, July 1936, page 388.

ITALY

Air and Water. The largest military airport in Italy has been opened at Froli. It covers 300 acres and is capable of accommodating 250 machines. Brief reference. Engineer, September 25, 1936, page 317. A recent decree of the Italian Government authorizes an increase of 34,000 men on the ground staff of the Regia Aeronautica. Aeroplane, September 2, 1936, page 296.

POLAND

Polish Arms and French Machinations. The French method of helping Poland to rearm is criticized and reference is made to the airplanes to be supplied. The Polish Air Force is said to have "a lot of its own single-seater fighters which in many respects are superior to any fighters on the continent of Europe with the exception of those countries which have bought British fighters or built to British designs." Brief. Aeroplane, September 16, 1936, page 345.

U. S. A.

Curtiss-Wright P-36. New single-seat, low-wing pursuit monoplane purchased by the Army Air Corps. Brief reference. Aviation, October 1936, page 45. 1 illus. Photograph only of the Curtiss YIP-36 with reference to construction. U. S. Air Services, October 1936, page 18. 1 illus.

Foreign Service News. "An attempt to bump off a Blimp, or at least discourage lighter-than-air enterprise on the part of the U. S. Army." Report that the TC-13 airship was shot at twice by an anonymous marksman who hit it and caused the loss of helium gas to the tune of several hundreds of dollars. Brief reference. Aeroplane, September 30, 1936, page 416.

The Four Winds. With G type Wright Cyclones of 800-odd hp. each the Martin B-10-B bomber does 240 m.p.h. Brief reference. Flight, October 1, 1936, page 335.

Seversky Trainer. Greater speed range, higher performance, and improved instrument equipment are the improvements in the new XBT basic trainer. Brief details. Seversky Aircraft Corporation is said to be low bidder in the latest competition for Air Corps basic trainers. Aviation, October 1936, pages 44–45. 1 illus. Western Flying, October 1936, page 28.

Air—Hot and Otherwise. F. A. Tichenor. Congressional appropriations for the production of gas masks for civilians and those in the military services are urged and the action taken by England, Germany and France in this matter is pointed out. Aero Digest, September 1936, page 27. 1 illus.

Air Services. Air Corps orders for Stearman PT-13 primary trainers, Curtiss V-1-P-36 pursuit planes, and Wright Cyclone engines are referred to. Mention is also made of the two test flights recently completed by the TC-13 airship. Brief references. Aero Digest, September 1936, pages 66–68.

Irrational Ira. Major Ira T. Eaker's flight from New York to Los Angeles made entirely by instruments. Brief comment. Aeroplane, September 9, 1936, page 322.

Maneuvers, Orders. Air raids staged in connection with the maneuvers of the Second Army Air Corps orders for 150 Wright Cyclone engines and Curtiss Y-1P-36 single-seater pursuits, and bids on basic trainers made by North American, Seversky and Northrop. Brief references. Aviation, September 1936, page 53.

New Shortcuts in Bombardment Training. Methods of training bombing pilots and bombardiers for the Air Corps are described with special reference to the use of the "camera obscura." Quotations from the Air Corps News Letter. A photograph of the Boeing "299" (YB-17) is included. U. S. Air Services, September 1936, pages 30–31. 1 illus. Scientific American, October 1936, pages 196–197. 7 illus.

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Foreign Service News. Two thousand soldiers armed with rifles or machine guns descended by parachute simultaneously from airplanes during the Moscow Military District maneuvers. They had travelled 260 miles by air and were unobserved by the defending force until they had imprisoned the radio operators. Brief reference. Aeroplane, September 30, 1936, page 416. Editorial criticism of the value of such practice in European warfare. Brief. Flight, October 1, 1936, page 331.

Foreign Service News. In the recent Russian Red Army maneuvers aircraft took a prominent part and hundreds of infantrymen with full equipment dropped by parachutes to blow up a bridge. Two Russian-built airships, the existence of which had been kept a close secret, flew over Minsk. Brief reference. Aeroplane, September 16, 1936, page 356.

The Communist Russian Aircraft Industry. Several hundreds of light twin-motor bombers have been produced in the shops of Factory 22 at the rate of four a day. These do over 250 m.p.h. At Nijni-Novgorod they are turning out five modern fighters a day. Impressions received by Louis Breguet on a visit to Russia. Brief. Aeroplane, September 2, 1936, page 292.

Air Warfare

The Anglo-Egyptian Treaty. Articles from the recently signed Treaty which are of aeronautical interest. Aeroplane, September 2, page 289.

Determined Aggression—By Bombers. B. J. Hurren. "The task of the bomber is considerably lightened by the meteorological officer and in the next war he will be a very overworked and important gentleman." The increasing importance of accurate meteorological information for use in long-distance raids and reconnaissances is pointed out and average yearly weather records for England, France and Germany are summarized. Flight, September 10, 1936, pages 272a–272b. 2 illus. 2 tables.

The Principles of War and the R.A.F.—Security. Defense of the British people and their industries from the menace of air attack. Operation from a secure base, and security for the lines of communication and the operational unit are outlined in a general discussion of the problems. Royal Air Force Quarterly, July 1936, pages 300–306.

The Protection of Large Plants for Reserve Supplies of Mineral Oil from Aerial Attack. P. di Amburgo. Precautions to be taken in the design of buildings for the reserve supplies of mineral oils, in order to protect them from aerial attack. Abstract from Gasschutz und Luftschutz, May 1936. Rivista Aeronautica, August 1936, pages 180–181.

Air Strategy. Lt. General N. N. Golovine. Military characteristics, armament, and duties are described for the four types of aircraft which comprise the armament of the proposed Independent Air Force. These types are the destroyer, the high-performance bomber, the scout for long-range strategic and reconnaissance, and a light single-seater fighter. An air-defense system based on the use of modern high-performance aircraft is outlined. A 20-25 mm. automatic "canon" is recommended for the destroyer fighter. As part of the equipment for the scout, an automatic camera using infra-red film and an electric dictaphone for recording information are suggested. Continuation. Royal Air Force Quarterly, July 1936, pages 261–299. 10 illus. 4 tables.

Fire Between Airplanes at Great Distances. Captain C. Colangeli. A further discussion of the author's theory which refutes the objections raised in an article in the June issue. Rivista Aeronautica, August 1936, pages 161–164. 1 illus.

Ground Defence Against Hostile Aircraft. A. L. Rawlings. A Douglas airplane is said to be capable of carrying a load of 2 tons of bombs at about 170 m.p.h. and to have a radius of action of over 3000 miles, while a Boeing bomber recently flew the 2100 miles from Seattle to Dayton carrying a comparable load at a speed of 233 m.p.h. Defense by land batteries and difficulties in hitting an airplane with them are discussed. The author considers the most promising line of development to be the provision of a sensitive reliable detector of the infra-red rays emitted by the hot aero engine. In the discussion Wing Commander Cave-Brown-Cave refers to such a predictor and states that he believes American manufacturers have brought their devices to the knowledge of the British War Office. Abstract of paper presented before the British Association. Engineer, October 2, 1936, pages 358–359.

The Navigation Problems of an Air Striking Force. Flight-Lieutenant F. M. V. May. The navigational problems discussed are those which arise in making a wing rendezvous and departure from the coast, in wind finding and navigation out of sight of land, in interception and return, in attacks against military or industrial objectives inland of the enemy frontier, and in training of navigators for high-speed aircraft in time of war. Royal Air Force Quarterly, July 1936, pages 313–322. 3 illus.

The Diary of Spain's Private War. Operations of aeronautical interest in the Spanish Revolution during the period August 16 to September 6. Aeroplane. August 26 and September 2 and 9, 1936, pages 260, 296 and 322.

Foreign Service News. Reinforcements for the Spanish anti-Government forces continue to arrive by air from Morocco. General Franco's new troop carriers are said to have landed 14,000 men from Ceuta at the airport near Jerez and ammunition and artillery have also been transported across the Straits by air. Brief reference. Aeroplane, September 16, 1936, page 356.

Miscellaneous

Remote Control. Teleflex system of mechanical remote control. The push-pull movement is transmitted through a patented continuous cable. Few details. Aeroplane, September 16, 1936, page 368. 1 illus.

Glazing Problems in Aircraft Cabins. R. A. Miller. Physical properties of several kinds of safety glass for aircraft cabins are compared with those of ordinary glass and their sound-proofing and insulating properties are discussed. Particular reference is made to Herculite, Duplate, Duolite, Aerolite and Crystalex. Aero Digest, September 1936, pages 22–23, 82 and 84. 3 illus. 1 table.

Equipment and Methods. Anti-corrosive for incandescent floodlight lamps, insulated loop antenna developed by TWA, Milburn MM paint spray gun, Electric Specialty motors for operating flaps and landing gears, and Homestead Model E Hypressure Jenny heavy-duty cleaning unit. Few details. Aero Digest, October 1936, page 66. 2 illus.

Bloctube Controls. The Tampier system which is to be introduced in America consists essentially of control tubes and ball joints designed to provide positive control and eliminate play, and to simplify maintenance. Two types of joint, the "ball lever" and the "ball tube," are used. Few details. Aviation, September 1936, page 35. 2 illus.

Land Launched Seaplanes. Captain F. T. Courtney. A system is proposed for launching heavily loaded flying boats. Estimates given bring a normal flying boat of 40,000 lb. gross weight and 30 lb. per sq. ft. up to 67,000 lb. gross weight and 50 lb. per sq. ft. for long range purposes. An acceleration between ¼ and ½ G., a launching run of 3000 ft., towing the launching carriage by means of cables operated by a stationary engine, a tilting platform and turn table for the airplane, and a method of control from the cockpit are suggested. The author believes such a launching system would be of immense military and commercial value. Aviation, September 1936, pages 19–21. 4 illus.

New Link Trainer. Chief improvement in the new Link advanced ground trainer is an automatic course recorder which traces the course "flown" by the student. In addition to the turn-and-bank indicator, air-speed motors, rate-of-climb indicator, and magnetic compass, the new trainer also has a sensitive altimeter, directional gyro, artificial horizon, radio compass, radio marker beacon indicator and a throttle. Brief description. Aviation, September 1936, pages 37–38. 2 illus.